THE UNIVERSITY OF QUEENSLAND

Bachelor of Engineering Thesis

Critical Analysis of the Queensland Metalliferous Mines Fatal Accident Record

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ABSTRACT

Safety is one of the most important areas of focus in the minerals industry. Queensland's metalliferous mines and quarries have experienced 1081 fatalities over the last 139 years, many of which had recurring causes and all of which were preventable. Recurring mistakes and fatalities can result in financial, political, trade union and social consequences for companies and the only way that the cycle of recurring fatalities can be broken, is by learning from historical failures and preventing their recurrence.

This project analysed historical fatality data by examining over 21 different influencing parameters to identify common hazards, causation factors and activities that result in the recurrence of fatalities. The intended purpose of this study is to enable the minerals industry to identify key areas where safety performance can be improved.

The analysis revealed that Safety and Health Legislation seem to have positively impacted upon the safety performance of the industry by reducing both the quantity and variation of annual fatal accidents to a level where a single fatality per year is now regularly achieved.

Multiple data trends and clusters identified a range of fatality causation patterns: Zinc-Lead-Silver and Copper-Gold were found to be the most fatal commodities mined with Mount Isa Mines accounting for the single most site-specific fatalities, normalised fatality data indicated that surface fatalities were 10 % more likely than underground fatalities, mid-week days and Fridays dominated fatality trends possibly pointing to mental fatigue and distractions, equipment operators represent the occupation most at risk of fatal accidents with LHD operators particularly susceptible and gravity was determined to be the most hazardous uncontrolled energy source on mine sites. However, it was the involvement of loaders and the inadequate utilisation of PPE and SWPs that were identified as the fatality causation factors that require immediate improvement throughout the industry to yield improved safety performance.

Gender, age, level of production, depth of operation and mining method were all found to have had no discernible impacts on fatality rates.

The necessity to communicate this fatality information, learn from it and rapidly evolve Safety and Health Management Systems on sites is the core conclusion reached. This requires that companies utilise fatality information as an auditing tool to continuously improve their Safety and Health Management Systems and site procedures every time a fatality occurs within the industry.

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1 INTRODUCTION

1.1 PROJECT BACKGROUND

Over the last 139 years, there have been 1081 fatalities within Queensland's metalliferous mines and quarries. In the last 50 years alone, spanning from 1966 to 2016, Queensland's metalliferous mines and quarries experienced 146 fatalities (Devine, 2017). The unfortunate theme that becomes evident when examining Queensland's mining fatalities is the fact that effectively all the fatalities were preventable. The recurrence of fatalities with common causes within the industry has also created concerns that mining companies are at times too slow to learn from historic fatal accidents and to update their sites' safety and health management systems to prevent the recurrence of fatalities. The cycle of recurring fatalities can only be broken by learning lessons from past fatalities and by preventing the mistakes from being repeated.

Mining safety and health legislation has the purpose of providing companies with a statement of the legal obligations and regulations that need to be adhered to, in order to ensure a safe working environment. Companies comply with legislation and therefore reduce the risks on their sites by documenting processes and procedures that are incorporated into the site's safety and health management system (SHMS) (Devine, 2017).

The evolution of Queensland's mining legislation has historically been driven by the lessons learnt from fatalities and accidents within the industry. This is particularly true for coal mining legislation where major disasters that resulted in multiple fatalities directly influenced the legislation. The royal commission into the Mt Mulligan disaster was followed by the Coal Mining Safety Act 1925 and similarly, the inquiry into the second Moura explosion in 1994 was followed by the Coal Mining Safety and Health Act 1999 (Mine Safety Institute of Australia Pty Ltd, n.d.). These disasters had pronounced impacts on the coal mining legislation and the lack of disasters of the same magnitude within the metalliferous mining industry has generated concern that the legislation governing metalliferous mining and quarrying has not evolved to the same extent as the legislation of the coal mining industry, possibly putting the metalliferous industry at risk of an impending disaster.

In Queensland, a company's management and Site Senior Executive are responsible for the effective implementation of the SHMS on site. However, due to the vast variety of tasks carried out on site, individual risk assessments are also required to identify and manage all the risks applicable to a specific task and this therefore ensures that the SHMS is applied to every situation. Risk assessments can also serve as an auditing process for the SHMS. If risks are identified, through risk assessments, for which the SHMS does not contain any documented provisions, this presents an opportunity to improve or update the SHMS (Devine, 2017).

When the SHMS and risk assessments used on site fail to prevent a fatality from occurring, the causes of the failure need to be investigated. In the pursuit of zero harm, it is crucial that these fatalities are thoroughly assessed, analysed and the results reported, so that the knowledge obtained may be used to eliminate any deficiencies in the SHMS or the legislation. This newly gained knowledge should be used to continuously audit and amend the relevant legislation and safety and health management system to ensure that they remain effective and to ultimately prevent similar fatalities from recurring.

This process can be described as a continuous improvement process which gets repeated every time a fatality occurs.

1.2 PROJECT DEFINITION

The safety of Queensland’s mining employees is a top priority at every mine site within the state. In the pursuit of zero harm, thorough analysis and communication of historical fatality data has an important role in evolving both the relevant mining legislation and a mine site’s safety and health management system. Devine (2017) states that: “Legislation is the law based on previous learning and community expectations on how best to avoid accidents and disasters”.

Kletz (1993) states that the reason organisations keep repeating their own and others’ mistakes is due to inadequate utilisation and communication of past accidents. He suggests that to improve safety and to improve corporate memory, historical accidents need to be systematically analysed and the lessons learnt need to be communicated to all concerned. This process can be described as a continuous improvement process which gets repeated every time a fatality occurs.

The purpose of this project is to provide useful information that can be used to learn from past fatalities and to aid the continuous improvement of mining legislation and SHMS.

1.3 AIMS AND OBJECTIVES

The aim of this project is to analyse historical fatality records to identify common activities, factors and hazards that contribute to the occurrence of fatalities by focussing on trends and clusters within the fatality data from 1986 to 2016.

It is intended that the identification of past failures will urge companies to rapidly and continuously evolve their site SHMS to prevent the recurrence of these fatalities within the industry. This will provide the information that the minerals industry requires to break the cycle of fatality recurrence and lead to continuous improvements of site SHMS.

To achieve the stated aim, the following objectives will be pursued for this project:

- Substantial research will be conducted to identify the details surrounding the fatalities that occurred from 1986 to 2016;
- Statistical analysis of the fatality data will be performed to determine whether any correlations exist between the fatalities and the investigated influencing factors;
- The effectiveness of Safety and Health Legislation in reducing the occurrence of fatalities within the industry will be assessed;
- Fatality data will be analysed to identify data clusters and trends that highlight key areas where safety performance improvements are required;
- A comprehensive source of fatality related information that can be utilised for the continuous improvement of current Safety and Health Management Systems and legislation will be created; and
- The fatality related information will be documented in a format that is easily understood and useful to potential users of the information.

The information that result from the analyses will be used to make broad ranging recommendations for improvements to the industry's safety performance. It will also serve as a knowledge database to be used by the mining industry to learn from previous failures and to prevent history from repeating itself.

1.4 SCOPE

This project is focussed on analysing fatalities that occurred over the last 139 years at metalliferous mines and quarries within the state of Queensland, Australia.

The following influencing factors will be analysed to establish whether any correlations with mine fatalities exists:

- Sex and age of individuals;
- Years of industry experience and years of training received by individuals;
- Geographic location and size of mine;
- Underground or surface operation;
- Fatality occurrence during development or production activities;
- Mining method employed and rate of production at time of fatality;
- Commodity mined and mine site at which the fatality occurred;
- Classification of the hazardous energy source that caused the fatality;
- Involvement of equipment, machinery or plant in the incident;
- Fly in fly out or residential classification of the deceased;
- Time of day and day of week that the fatality occurred;
- Number of employees in the industry;
- Changes in legislation;
- Contractor or company employed individuals; and
- Depth of mining operations where fatality occurred.

1.5 PROJECT SIGNIFICANCE AND RELEVANCE TO INDUSTRY

The safety of Queensland’s mining employees is a top priority for the industry. This is demonstrated by the comprehensive safety programs implemented by various companies within the industry (Verra, Tate and Dryden, 2006).

Mining companies have realised that safety management is not exclusively a financial burden and to the contrary, effective safety management plans can conversely result in financial benefits to the company implementing them.

Ekevall, Gillespie and Riege (2008) identified various financial benefits related to improved safety performance and strong safety records, including:

- Increased access to external capital;
- Reduced litigation costs;
- Reduced insurance costs and accident damage premiums;
- Reduced production delays;
- Preventing lost sales and reduced share prices resulting from a tarnished reputation; and

- Increased tendering success for mining contractors.

The benefits of effective safety management also extend to political, trade union and community factors.

Furthermore, the evolution of mining legislation and site SHMS depends on the knowledge generated from the analysis, interpretation and reporting of historic fatalities.

Therefore, thorough analysis and interpretation of Queensland's metalliferous fatal accident record will serve as a critical source of information to the minerals industry. This information can then be incorporated as inputs to address any deficiencies in legislation or the Safety and Health Management Systems of mine sites. The subsequent improvements to safety that could occur, would yield financial, political and community benefits to the stakeholders while also preventing recurrence of mining fatalities.

1.6 PROJECT MANAGEMENT

1.6.1 Project Risk Assessment

The successful completion of this project, as with any project, is subject to avoiding the hazards and mitigating the risks that could affect its progress. In order to assess, identify and control any potential hazards that the project might face, a thorough risk assessment was performed. The risk assessment, included in Table 3, identified the hazards applicable to the project and used Tables 1 and 2 to establish the consequence and likelihood of the associated risks, while the matrix in Figure 1 provided the risk with a ranking. Once the risk was ranked, mitigating controls were proposed and the risks were re-assessed to determine their risk rankings after the controls were implemented.

	Consequence				
Likelihood	5 - Insignificant	4 - Minor	3 - Moderate	2 - Major	1 - Catastrophic
A - Almost certain	High (H)	High (H)	Extreme (E)	Extreme (E)	Extreme (E)
b - Likely	Moderate (M)	High (H)	High (H)	Extreme (E)	Extreme (E)
C - Possible	Low (L)	Moderate (M)	High (H)	Extreme (E)	Extreme (E)
D - Unlikely	Low (L)	Low (L)	Moderate (M)	High (H)	Extreme (E)
E - Rare	Low (L)	Low (L)	Moderate (M)	High (H)	High (H)

Figure 1. Risk ranking matrix (Campos-Rojas, 2016).

Table 1

Risk matrix consequence definitions.

Rank	*Consequence*	*Definition*
1	Catastrophic	Irreversible, detrimental effects on time loss or report quality. The project is delayed past the due date for completion and minimum quality standard is not achieved
2	Major	Prolonged but reversible effects on time loss. The project is completed after the deadline to a low quality
3	Moderate	Short term detrimental effects on time loss or report quality. The project is completed within the deadline but to a lower quality
4	Minor	Minor short term effects on time loss or report quality. The project is completed within the deadline with minor losses in terms of quality
5	Insignificant	No detrimental effect on time loss. Quality is preserved.

Source: Campos-Rojas (2016)

Table 2
Risk matrix likelihood definitions.

Rank	*Likelihood*	*Definition*
A	Almost certain	The event is expected to occur in most circumstances (at least once per week)
B	Likely	The event will probably occur in most circumstances (at least ten times per year)
C	Possible	The event could possibly occur at some time (at least twice per year)
D	Unlikely	The event could possibly occur at some time but is unlikely (at least once per year)
E	Rare	The event may occur only in exceptional circumstances (less than once per year)

Source: Campos-Rojas (2016)

Table 3
Project risk assessment and proposed risk mitigation.

Hazard	***Description***	***Likelihood***	***Consequence***	***Risk Ranking***	***Proposed Control***	***Improved Likelihood***	***Improved Consequence***	***Improved Risk Ranking***
Technological Failure	Analysis and/or report progress is lost due to a technological failure or data corruption	C	1	Extreme	Regularly save progress copies of all work in multiple locations (USB, cloud storage and external HDD)	C	5	Low
Extra-curricular responsibilities	Responsibilities of role as president of the AusIMM Southern Queensland Student Chapter leads to time constraints	B	3	High	Manage time effectively by allocating hours towards thesis work and student chapter responsibilities every week	C	4	Moderate
Illness or injury complicating communication and/or progress	Either student or supervisor becomes ill or gets injured, hampering discussions and report progress	C	3	High	Attempt to be at least two weeks ahead of schedule with thesis progress to reduce the impact that illness or injury could have on the thesis. Immediately advise supervisor and course coordinator of any serious or repeated illnesses or injuries.	C	4	Moderate

Transportation complications/ traffic delays	Supervisor and student meetings delayed due to considerable traffic between Deception Bay and the University of Queensland. Public transport delays or cancelled services	B	4	High	Plan transport routes in advance and utilised live traffic tracking software to ensure sufficient time for travel has been factored in. Determine whether alternative transport methods might be faster if delays are expected.	C	4	Moderate
Insufficient data	Fatality data lacks the required detail needed to complete the project to the required standard	C	2	Extreme	Identify all data requirements early and develop a plan to contact external sources to obtain additional information. Alternatively, develop a plan in consultation with supervisor to work around data deficiencies	D	3	Moderate
Breach of confidentiality	Additional data obtained from sources personally contacted by student might be subject to confidentiality requirements that would be breached by publication of the report	D	2	High	Clarify whether obtained data is confidential when obtaining it from sources. If confidentiality is applicable, contact Mechanical and Mining Engineering School to obtain advice on how to comply with confidentiality requirements. Save data files to secure locations only.	E	3	Moderate

Supervisor unavailability	Supervisor might be unavailable on certain days or might be out of town for periods of semester	C	3	High	Arrange key meeting times well in advance and communicate via email or Skype when physical meetings might not be possible	D	5	Low
Late submission	Report might be submitted past the set deadline for multiple reasons	E	1	High	Plan project work completion date in advance of university deadline. Continuously upload draft versions of report. Continuously assess project progress to ensure key milestones are achieved and allocate additional time to project if progress is deemed insufficient according to predetermined Gantt chart	E	3	Moderate
Project submitted is of insufficient quality	Project might not meet required criteria due to multiple reasons	D	1	Extreme	Complete tasks outlined in project criteria and seek feedback from supervisor prior to submission. Complete project work with sufficient time to perform quality assurance	E	3	Moderate

Risk assessment becomes ineffective	New risks are introduced to the project or controls become obsolete	B	3	High	Continuously review and if necessary update the risk assessment	D	4	Low

All the risks identified and controlled for in Table 3 had their risk rankings reduced to either low or moderate rankings which are deemed sufficient for the purposes of this project.

1.6.2 Project Timeframe

1.6.2.1 Project Milestones

The successful completion of this project is dependent on a range of key tasks that will have to be completed as the project progresses. The key milestones applicable to this project are contained in Table 4. These milestones relate to tasks that are crucial to achieving the objectives of the project as well as tasks that will form part of the project's formal assessments.

Table 4
Significant Project Milestones.

Milestone	*Due Date*
Project Plan Agreement	1/06/2017
Fatality database completed	7/08/2017
Statistical analysis completed	25/08/2017
Thesis Synopsis	8/09/2017
Thesis Presentation Slides	26/09/2017
Project Presentation	29/09/2017
Examiner's Copy of Thesis	09/10/2017
AusIMM Proceedings – Conference Paper	27/10/2017
Revised Copy Thesis	6/11/2017

1.6.2.2 Project Gantt Chart

To highlight the importance of achieving the identified milestones and how they form part of the overall completion of the project a Gantt chart was produced, using the Gantt Project software program, that illustrates the project's critical path and where the milestones are applicable to this pathway. Appendix B contains the output produced by the Gantt Project software. It illustrates the required activities that need to be completed along with the start and end date applicable to each activity. It also visually illustrates the activities identified in the form of a Gantt chart.

The Gantt chart displays the required activities as grey bars with lengths equivalent to the estimated time required to complete the activities. The project milestones are displayed as diamonds while black arrows indicate the interdependencies of the project. There are two grouping brackets, one blue and one black, which indicate continuous formatting and editing as well as ongoing supervisor consultation respectively; these activities span over multiple months and will be undertaken alongside other activities throughout the project's life.

The project's critical path has been identified; the critical path is highlighted in black and can be followed by observing the black diamond shaped milestones and black striped bars on the Gantt chart. The critical path follows the project report's progression from the submitted progress report to the final, revised report that will be submitted to the project's supervisor. The critical path, excluding assessment milestones, requires:

- That the causes of the fatalities in the project's database be researched;
- Completion of the fatality database;
- Statistical analysis of the fatality database;
- Discussing the significance of the statistical findings within the context of the current regulatory framework;
- Recommendations with respect to safety improvements and additional research requirements; and
- Producing a high-quality report that communicates the project's results.

1.6.2.3 Contingency Planning

Due to the significant importance of the activities that comprise the critical path of the project, these activities where allocated timeframes that exceed the expected time required to perform them. This was done in an attempt to mitigate the risks identified, should they occur. The timeframes allocated to the critical path activities will allow ample time for the activities to be completed even if unexpected delays were to occur.

There are no significant software or financial requirements for the completion of this project. Any additional data will be sourced online and statistical analysis will be performed with Microsoft Excel software which is widely available on all campus computers.

2 LITERATURE REVIEW

2.1 THE PURSUIT OF ZERO FATALITIES

Darling (2011) writes that one of the most significant issues facing mine managers today is the objective of achieving a safe work environment, often described by the phrase “Zero Harm”. The phrase zero harm expresses the mission of most mining companies, contractors and mining employees when it comes to safety. Safety forms one of the five dimensions of sustainable mining, emphasizing the importance of preventing all mining fatalities; especially those fatalities that are related to recurring causes, to ensure the sustainable future of the minerals industry (Darling, 2011). The five dimensions of sustainable mining practices are illustrated in Figure 2.

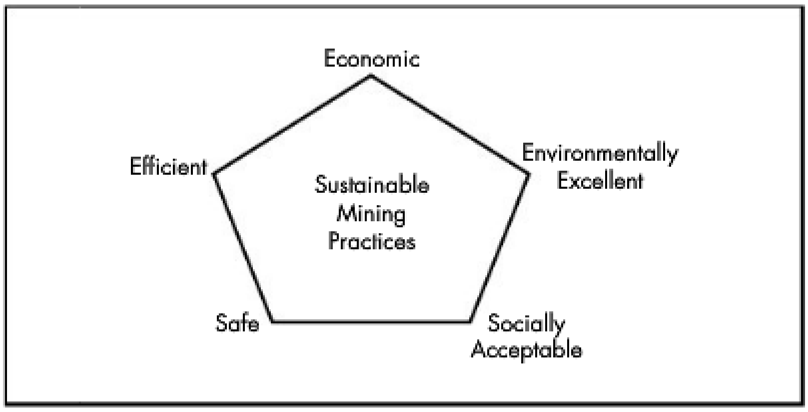

Figure 2. The five sustainable mining practices (Darling, 2011).

The Minerals Council of Australia (MCA) strongly supports the pursuit of zero harm and reinforces its position by stating that “all mining fatalities are preventable” (MCA, 2017). The MCA defines its vision for mining safety as “An Australian minerals industry free of fatalities, injuries and diseases” and supports its vision by declaring that:

- “All fatalities, injuries, and diseases are preventable;
- No task is so important that it cannot be done safely;
- All hazards can be identified and their risks managed;
- Everyone has a personal responsibility for the safety and health of themselves and others; and
- Safety and health performance can always be improved” (MCA, 2017).

The pursuit of zero harm is fundamental to the future of mining and is recognised by many authors and industry professionals, yet achieving zero harm seems to continually evade the minerals industry. While the occurrence of fatalities in the mining industry can be attributed to a range of factors including safety legislation, safety culture, company management, worker behaviour, human errors and natural disasters, it is expected that the industry would do everything in its power to learn from fatal accidents and prevent fatalities from recurring. It is only by ensuring that historical fatal accident information is available, understood and comprehensively analysed that adequate measures can be developed and implemented to prevent their recurrence.

2.2 OVERVIEW OF QUEENSLAND'S CURRENT METALLIFEROUS MINING SAFETY AND HEALTH REGULATORY ENVIRONMENT

In Australia, the major mining states have separate regulatory regimes governing the safety and health of workers in the minerals industry. This approach has been justified by the sufficiently different hazards, mine site cultures and circumstances surrounding mining operations in each state (Gunningham, 2005). Additionally, it is important to note that mining in Queensland is considered to be sufficiently different from other industries in the state to warrant its own statutes and regulations with respect to occupational health and safety. This implies that the enforcement of and inspection of mines' compliance with the safety and health regulations are governed by mining specific legislation. In order to effectively analyse fatal accidents in the mining industry, it is important to have a sufficiently comprehensive understanding of some of the key concepts of the regulatory environment.

2.2.1 Legislative Elements

Metalliferous mining and quarrying in Queensland is governed by the *Mining and Quarrying Safety and Health Act 1999* (QLD) together with the act's accompanying regulation, the *Mining and Quarrying Safety and Health Regulation 2001* (QLD). Other safety and health aspects of mining governed by separate legislation includes explosive activities governed by the *Explosives Act 1999* (QLD) and radiation aspects governed by the *Radiation Safety Act 1999* (QLD).

Other statutory instruments include:

- Guidelines issued by the Minister for Natural Resources and Mines under the Mining and Quarrying Safety and Health Act 1999 (QLD) s. 63(1). These guidelines establish methods for achieving an acceptable standard of risk for people working in metalliferous mines and quarries;

- Directives issued by the Mines Inspectorate under the Mining and Quarrying Safety and Health Act 1999 (QLD). These directives are normally applicable to a specific mine or group of mines and are intended to reduce risk to an acceptable level; and
- Letters issued by the Mines Inspectorate under the Mining and Quarrying Safety and Health Act 1999 (QLD). These letters are again typically applicable to a specific mine or group of mines.

2.2.2 The risk management approach of current mining safety legislation

The current Mining Safety Act is written in a manner that requires the management of risks to keep them at an acceptable level or as low as reasonably possible instead of prescribing specific technical requirements that are characteristic of historical prescriptive Acts. Joy (2004) states that the control of risks is required to comply with Occupational Health and Safety Acts, the Mining and Quarrying Safety and Health Act 1999 (QLD), Environmental Protection Acts and to protect mining companies from litigation resulting from accidents and fatalities.

The risk-based approach is implemented via risk management which can generally be summarised by the following steps:

- A scoping assessment is conducted to identify hazards associated with specific operations;
- A qualitative or semi-quantitative risk analysis is performed to establish the magnitude of potential consequences as well as the likelihood of occurrence associated with the identified risks;
- Decide on suitable measures for controlling, mitigating or eliminating the risks outlined;
- Control measures are implemented;
- Audits and a continuous improvement process assesses the efficiency and effectiveness of the controls in reducing and managing risks; and
- An assessment of residual risks is performed (Poplin et al., 2008; Joy, 2004).

The risk assessment process outlined above is in accordance with the intent for risk management established in AS/NZS ISO 31000:2009, the Australasian adopted international standard on risk management (Joy and Griffiths, 2007). The risk management process model, recommended by AS/NZS ISO 31000:2009, is illustrated in Figure 3.

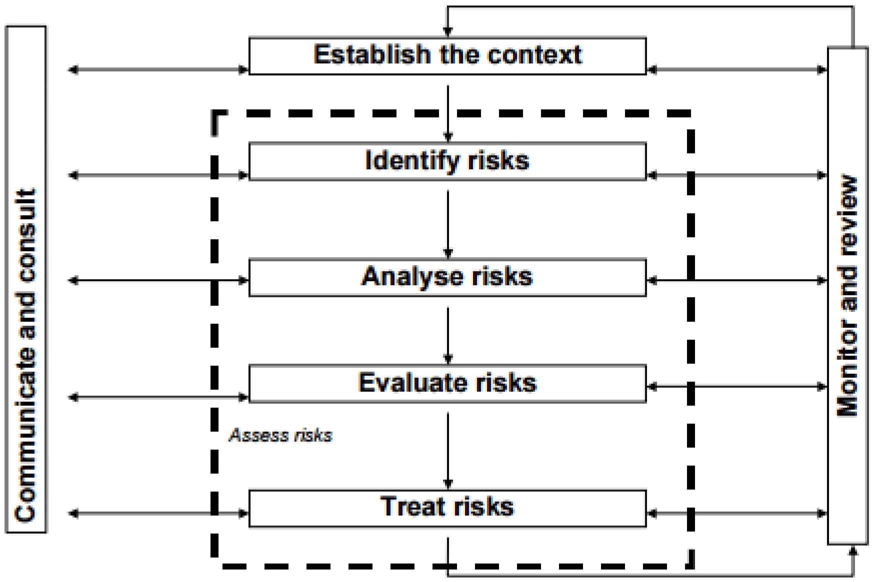

Figure 3. Risk Management Process Model (Joy and Griffiths, 2007).

The most common risk assessment techniques employed in Australia to manage mining risks are:

- Informal risk assessments;
- Job Safety/Hazard Analysis (JSA/JHA);
- Standard Operating Procedures (SOP);
- Preliminary hazard analysis (PHA);
- Workplace Risk Assessment and Controls (WRAC);
- Hazard and Operability Studies (HAZOP);
- Fault Tree Analysis (FTA);
- Event Tree Analysis (ETA); and
- Failure Modes, Effects and Criticality Analysis (FMECA) (Joy, 2004).

2.2.3 Statutory bodies and positions

2.2.3.1 Department of Natural Resources and Mines (DNRM)

Compliance with Queensland's metalliferous mining legislation is enforced by the Mines Inspectorate which is an administrative unit of the DNRM. The Mines Inspectorate:

- Provides regulatory oversight;
- Conducts routine inspections of all mines in Queensland;
- Audits mining operations to ensure compliance with regulation;
- Issues directives described in Section 2.2.1 of this report;
- Deals with complaints related to safety matters;
- Investigates serious injuries and deaths on mine sites; and
- Prosecutes perpetrators of the Mining and Quarrying Safety and Health Act 1999 (QLD) (Bevan, 2008).

The DNRM is also responsible for the Safety in Mines Testing and Research Station (SIMTARS), a safety focused research unit in Queensland.

The department's Executive Director of Safety and Health is also responsible for the Petroleum and Gas Inspectorate and the Explosives Inspectorate (Bevan, 2008).

Queensland's mine safety administration hierarchy is illustrated in Figure 4 with the exception that the department is now the DNRM.

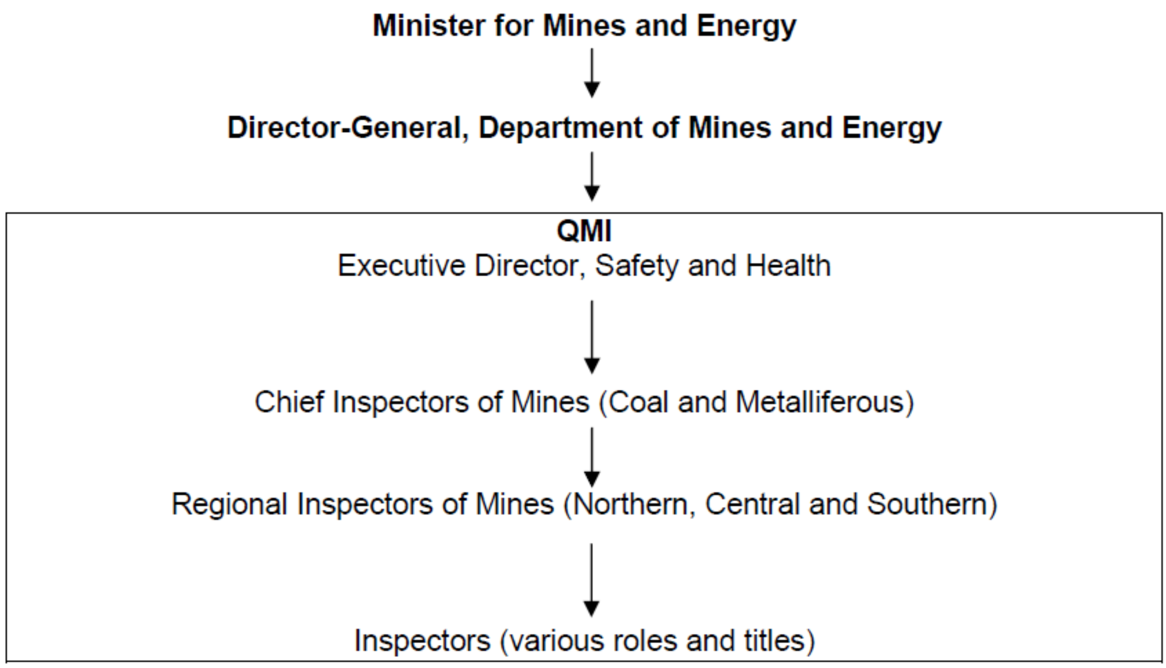

Figure 4. Queensland’s mine safety administrative hierarchy (Bevan, 2008).

2.2.3.2 District Workers’ Representative

Representatives appointed by the Minister to fulfil specific health and safety roles in the mining industry which includes the role of investigating complaints made about mining safety (Bevan, 2008).

2.2.3.3 Mine Operator (typically the owners of the mining operation)

Mine operators are responsible for implementing safety policies and practices at mine sites (Bevan, 2008).

2.2.3.4 Site Senior Executive (SSE)

The mine’s SSE is responsible for the mine’s operations and can conduct investigations into serious incidents on site (Bevan, 2008).

2.2.3.5 Site Safety and Health Representative (SSHR)

One of the mine’s employees who is selected by other employees and is tasked with inspecting and reviewing safety matters as well as investigating certain complaints about mine safety (Bevan, 2008).

2.2.3.6 Underground Mine Manager

Manages underground mining aspects of the site's operations.

2.2.3.7 Supervisors

Fulfil various safety oversight and management duties on site.

2.2.3.8 Other Mine Workers

All mine workers and visitors have safety obligations on site under the current legislation.

2.2.4 Other relevant entities

Relevant unions have the right to nominate individuals for certain statutory positions. They also form a crucial component during consultation processes, handle mine safety complaints and conduct training (Bevan, 2008).

The Queensland Resources Council (QRC) is "an independent body representing the commercial developers of Queensland's minerals and energy resources" (Bevan, 2008). The QRC can nominate individuals for certain statutory positions and forms a crucial component of the consultation processes related to mine safety matters.

2.2.5 Potential Deficiencies in the Current Regulatory Framework

To understand why certain fatalities keep recurring it is essential that the legal framework intended to prevent these fatalities is explored and well understood. In order to improve the regulations, mining fatalities need to be linked back to the mechanisms that were intended to prevent them from occurring to root out the vulnerabilities present in the regulation that might result in the recurrence of fatalities.

In examining Queensland's mining legislation, the requirement for a Safety and Health Act that is specific to the mining industry is justified by the perceived unique characteristics of the industry. It should however be questioned whether this separation from Safety and Health Acts applicable to other industries results in mining legislation that is susceptible to becoming outdated and lacks the potential improvements that would have resulted from fatalities that occurred in other industries. The aviation and medicinal industries are some of the most complex industries in terms of the hazards that are faced and the potential for human harm, however the level of controls implemented in the industries are of the highest standard. Mine safety could potentially be improved be incorporating lessons learned in other industries if the harmonisation of the relevant Safety and Health Acts were to occur.

It should also be noted that Queensland’s mine safety regulatory framework differs from the other mining states in Australia. These differences could potentially cause confusion for employees who relocate from one state to another. The MCA’s aim of reaching zero harm is a national initiative and the harmonisation of safety and health regulations from all the states into a Federal Act would encourage best practice nationwide and would seem like a possible progression towards zero harm in Australia’s mining industry.

Bevan (2008) lists some of the critical comments often directed at Queensland’s safety and health regulatory framework. The author states that the compartmentalisation of the Mines Inspectorate that places it under the control of the DNRM raises the concern that the Mines Inspectorate might not act in an unbiased manner when dealing with the mining industry. He attempts to reinforce this speculation by stating that the “often-perceived lack of prosecutions” that are pursued by the Mines Inspectorate following fatalities in the industry provides evidence for his argument. This comment should however be considered with care since the contrast to the scenario described by Bevan would result in an industry where excessive prosecutions by the Mines Inspectorate would discourage professionals from taking up positions such as mine managers due to the fear of prosecution should a fatal accident occur.

Bevan (2008) also notes that retaining mine inspectors with the required skill set and experience can be financially difficult due to the lucrative offers they receive to perform consulting services within the industry.

2.3 PRESCRIPTIVE VS RISK-BASED LEGISLATION

During the early 1990s, the Australian mining industry started investigating a new mining safety regulatory structure with the goal of reducing high fatality rates in the mining industry. This new structure was risk-based and derived from the “duty of care” based Robens-style legislation (Poplin et al., 2008). The current risk-based Queensland Mining Acts generally do not prescribe safety measures nor procedures; there are no checklists of technical requirements that can be ticked to ensure compliance (Bevan, 2008). The risk-based approach has been summarised in Section 2.2.2 of this report.

(Bevan, 2008) recognised substantial limitations existed in a prescriptive approach. His report noted that prescriptive legislation results in a mass of detailed and difficult to comprehend laws that are difficult to keep up to date and often fail to address all relevant issues. The report contrasts this with risk-based legislation which is flexible and innovative, establishing responsibilities in terms of requiring duty holders to take measures across the board and address new hazards as they emerge.

Poplin et al. (2008) utilised data describing the lost-time injury rates for coal mine sites in the USA, Queensland and NSW to assess whether the change from compliance-based to risk-based regulation in Australia significantly improved safety performance relative to North American mines which had continued to rely on compliance-based regulation. In performing the analysis, the authors used generalised estimating equations (GEE) to assess the trends among the mines as the method is robust with respect to imbalances and missing data points.

Poplin et al. (2008) used incident rate ratios (IRR) to account for confounding factors related to the size of the mine, the tons of coal produced and whether the mine is a surface or underground operation in an attempt to isolate the effect that the change in legislation had on the rate of injuries. The time trends for IRRs for the USA, Queensland and New South Wales are displayed in Figure 5.

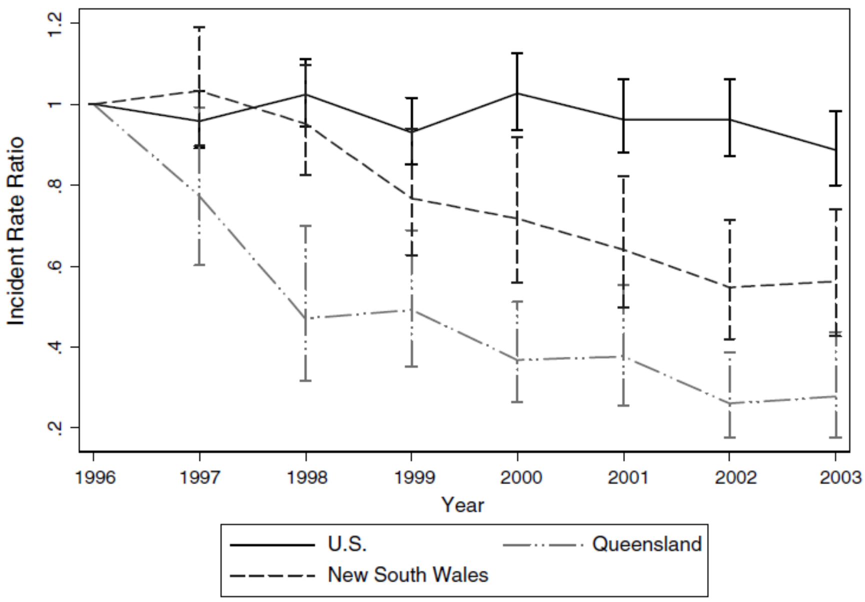

Figure 5. Illustration of time trends in IRRs for the USA, QLD and NSW (Poplin et al., 2008).

Figure 5 indicates observable reductions in the IRR trends for QLD and NSW while the IRR trend for the USA fluctuates around an approximately constant mean value of one. It should however be noted that risk-based *Coal Mining Safety and Health Act 1999* (QLD) and the *Coal*

Mine Health and Safety Act 2002 (NSW) were enforced after the IRRs had already started reducing. Poplin et al. (2008) explained that risk management processes had progressively begun to be implemented at mine sites in the early 1990s before it was enforced by legislation a decade later. The implementation of risk-based processes over the years leading up to the official dates of the legislation seems to correspond to significant decreases in the injury IRRs for QLD and NSW while the USA, governed by compliance-based regulation, did not enjoy similar successes over the same period.

Attitudinal surveys conducted by Laurence (2005) involving approximately 500 mine workers at 33 mines located in NSW, QLD and other international mine sites were also critical of compliance-based approaches to mine safety. Laurence discovered that increasing the magnitude of rules and regulations to cover every aspect of mining as well as developing detailed prescriptive regulations, safe work procedures and safety management plans failed to "connect" with mine workers, therefore failing to produce a safer mine environment.

Joy (2004) corroborates the findings of Poplin et al. (2008) by stating that risk assessment and management has become an integral part of coal mining in Eastern Australia, contributing towards reductions in loss time injury frequency rates (LTIFR) from pre-1988 levels sometimes exceeding 200 to 2004 levels of less than 20 LTIFR.

The full effects and performance of risk assessments in the mining industry have not yet been objectively measured and reported, however the attitude towards risk assessments and feedback from all levels of the mining industry have been positive (Joy, 2004).

2.3.1 Criticism expressed about risk-based legislation

One of the issues that arises when dealing with risk-based legislation is the issue of what exactly constitutes an acceptable level of risk. Contrary to prescriptive legislation, it can often be more challenging to objectively prove whether an acceptable level of risk had been maintained and whether the Act had been breached (Bevin, 2008).

The article written by Poplin et al. (2008) presents intriguing findings with respect to the possible correlation between risk-based legislation and reductions in injury incident rates. It should however be noted that the article does have its limitations. The first limitation noted is that even if correlation exists, it does not necessarily equate to causation. Additionally, the classification of what constitutes a reportable lost time injury is inconsistent among mine sites. Comparing the statistics for lost time injuries across countries, introduces high possibilities that the standards for reporting such incidents will vary considerably among the sites investigated. It is for this reason that this report will instead investigate mining fatalities as the classification of what constitutes a fatality is a universal measure.

Poplin et al. (2008) also acknowledges that the legislation governing mining in the United States is considered to be a hybrid between risk-based and prescriptive legislation instead of being classified as an outright prescriptive-based act.

The article by Poplin et al. (2008) should be analysed within its context, as it only investigated coal mines. For the purposes of this report, Queensland's metalliferous mines will be investigated and analysed in an attempt to establish whether a similar reduction in incidents is observed over the period that Queensland transitioned from a prescriptive-based act to a risk-based act. The measure of success will however be linked to the occurrence of fatalities instead of lost time injuries.

Finally, while the benefits of risk-based legislation seem to be apparent, mine sites face the difficult task of ensuring that risk mitigating measures such as risk assessments are consistently performed with due care. The risk exists that over time employees can become complacent in performing these risk assessments with the risk mitigating technique being reduced to a routine instead of a conscious attempt to reduce risk to an acceptable level.

2.4 THE ABSENCE OF MINING DISASTER INFLUENCE AND PRINCIPLE HAZARD MANAGEMENT PLANS FROM LEGISLATION FOR METALLIFEROUS MINES

One of the most noticeable differences between the coal and metalliferous mining industries in Queensland is the fact that historical, multiple fatality mine disasters have almost exclusively been limited to coal mines. These mine disasters have major impacts on public perception of the mining industry, political actions and legislative changes (Verra, Tate and Dryden, 2006).

Table 5 includes mining disasters that had significant impacts on the mining industry.

Table 5
Queensland mining disasters and their impacts on the industry.

Year	*Disaster*	*Description*	*Impact*
1921	Mount Mulligan Colliery	Dust explosion resulted in 77 fatalities	Resulted in the enactment of distinct legislation to govern coal

			and metalliferous mines respectively. Mines Inspectorate was divided into Metalliferous and Coal Inspectorates respectively.
1972	Box Flat No. 7 Colliery	Large scale explosion resulted while an attempt was made to put out an underground fire, claiming 18 fatalities	Mine rescue protocols were updated
1975	Kianga No. 1 Mine	Spontaneous combustion led to underground explosion resulting in 13 fatalities	Legislation was significantly altered and SIMTARS was established.
1986	Moura No. 4 Underground Coal Mine	A flame safety lamp triggered an underground explosion which resulted in 12 fatalities	Significant changes to emergency egress framework, committee tasked with determining the minimum training requirements for coal mines was established and flame safety lamps were prohibited
1994	Moura No. 2 Underground Coal Mine	Spontaneous combustion resulted in underground explosion, claiming 11 fatalities	Updates to gas monitoring protocols, alterations to emergency escape facilities, requirement for statutory certificates to be assessed periodically, requirement for mine safety management plans incorporating risk and hazard analysis and a

	review of the Mines Inspectorate.

Source: Verra, Tate and Dryden (2006)

The improvements detailed in Table 5 were accompanied by safety improvements that resulted from recommendations made by the Mining Wardens Court and Coroners Court (Verra, Tate and Dryden, 2006).

The disasters listed in Table 5 had significant impacts on Queensland's mining legislation in general, however the coal industry certainly underwent the most significant overhaul. The fact that these disasters were limited to the coal mining industry raises the question of whether the legislation regulating metalliferous mining and quarries in Queensland has been improved and refined to the same extent as the legislation governing the coal mining industry. The consequences of an inferior metalliferous mining legislation could translate to an increased possibility that a disaster affecting Queensland's metalliferous mining industry could occur.

A direct comparison of the Mining and Quarrying Safety and Health Act 1999 (MQSHA 1999) (QLD) and the Coal Mining Safety and Health Act 1999 (CMSHA 1999) (QLD) yielded the following substantial difference:

2.4.1 CMSHA 1999 Division 3, Section 63

The CMSHA 1999 (QLD) makes provision for a "Principal hazard management plan" in Division 3, Section 63 of the Act. This section requires the site's safety and health management system to include a principal hazard management plan capable of:

"(1) A principal hazard management plan must— (a) identify, analyse and assess risk associated with principal hazards; and (b) include standard operating procedures and other measures to control risk."

The section also requires that the SSE "…give a copy of the principal hazard management plan to a person that employs persons at the coal mine whose work is affected by the plan's requirements"

Failure to comply by the SSE can result in a maximum penalty of 200 penalty units.

The CMSHA 1999 (QLD) defines a principal hazard as a hazard with the potential to cause multiple fatalities.

A principal hazard management plan is a very notable omission from the MQSHA 1999 (QLD) which directly relates to a mine's requirement to manage hazards that could result in multiple fatality mine disasters. This could possibly be reminiscent of the fact that coal mining legislation has been shaped significantly by disasters. A report by the Department of Mines and Petroleum (2014) discovered that the majority of fatal accidents in Western Australian mines were caused by a relatively small number of accident types which highlighted the importance of principle hazard management plans.

It could be argued that the MQSHA 1999 (QLD) requires that all hazards have their associated risks reduced to an acceptable level, however the omission of a section on principal hazard management could result in a less diligent assessment of hazards that are particularly relevant to mass casualty mine disasters.

2.5 FATALITY CAUSES

Every mining fatality that occurs is unique and subject to case-specific factors, regulatory context and circumstances (Quinlan, 2014). Mannan (2013) states that the main aim of accident and fatality research should be to understand accidents to prevent them from recurring. The author continues to explain that attempting to understand an accident is often primarily equated to identifying the cause of the accident. In order to simplify the extensive historical database analysed in this report to a more manageable and meaningful information summary, the fatalities need to be categorised. The categories selected need to be adequately specific to provide meaningful information about the fatalities contained within each category and simultaneously, the categories need to remain broad enough to ensure each category contains sufficient fatalities to justify statistical analysis.

In an attempt to identify categories that could possibly be utilised to summarise the data, Table ***8*** in Appendix C was constructed by identifying common fatality causes from literature and referencing the amount of times the fatal cause was identified by different authors.

A report published by the Department of Mines and Petroleum on fatalities in the Western Australian mining industry, investigated mine fatalities in Western Australia that occurred between 2000-2012. The report identified the causes of accidents in accordance with trigger events which are included in Table 8 (Department of Mines and Petroleum, 2014).

The NSW Department of Planning and Environment's Division of Resources and Mining (DPEDRM) releases monthly incident summaries that categorise incidents and potential incidents according to causal factors that are described in Division 2, Section 145 of the *Mine Health and Safety Regulation 2007* (MHSR 2007) (NSW). The Mining and Quarrying Safety and Health Act 1999 (QLD) has a similar list of high potential incidents contained in Schedule 1 of the regulation. The mentioned legislative documents identify incident causal factors that are included in Table 8. These incident causal factors are not specifically intended to classify fatality causes, however they are useful in identifying hazards that could result in fatalities and for this reason, they are often used in reports related to mining fatalities.

Additionally, the New South Wales DPEDRM has published an incomplete database of international mining fatalities that classifies the fatalities contained within the database according to "Agent of Fatality". This report was published with a disclaimer informing the reader that the report was produced by engineering students undertaking internships with the NSW DPEDRM. Therefore, the agents of fatality disclosed in this report were screened to exclude categories deemed too vague for consideration. The agents removed and the reason for exclusion are outlined in Table 6.

Table 6
Agents of fatality excluded from analysis.

Agent of fatality filtered	***Reason for exclusion***
Catastrophic failure	Any number of failures can be classified as catastrophic, making the agent too ambiguous
Other explosion	Not related to a particular identifiable event
Uncontrolled release of energy	The majority of fatalities are related to trigger events that involve uncontrolled releases of energy
Unintended operation of equipment	Operation of equipment in a manner that results in the fatality of a mine worker will be classified as unintentional for any incident that does not have criminal motivation

In addition to the exclusion of the agents in Table 6, the following assumptions were made in relation to the agents identified by Noon and MacNeill (2008):

- “Fall of Roof/Sides/pit wall” was separated and considered as “rock or ground fall” or “Pit wall failure”; and
- Drowning was included in the category “immersion in liquid”.

The United States Department of Labour’s Mine Safety and Health Administration (MSHA) publishes data summaries that classify fatalities in metalliferous mines in the USA according to 18 different accident types. These fatality classifications have also been included in Table 8.

Mining fatalities can virtually always be attributed to some form of energy in the form of a hazard that triggered the fatal incident. Joy (2004) writes in an article that “damage cannot occur without the unwanted release of energy”. The author then provides a list of energy sources typically used to identify hazards or for the purposes of this report, to identify fatal incident causes. The list is as follows:

- Gravity;
- Electrical;
- Mechanical;
- Chemical;
- Pressure;
- Thermal;
- Radiation;
- Biomechanics; and
- Biological (Joy, 2004).

Quinlan (2014) writes that the mechanisms resulting in mining fatalities have been known for “hundreds of years” and are well documented. The author then lists eight hazards which have been included in Table 8 and referenced to Quinlan. During the author’s investigation, he considered mining fatalities from five different countries, including Australia, that occurred between 1975 and 2011. Quinlan identified ten patterns that were repeated in the identified fatalities and recommended the following categories for classifying the causes of mining fatalities:

- “Design, engineering, technical and maintenance failures;
- Warning signs that were ignored;
- Failures in risk assessment;
- Failures in management systems and hazard management plans;

- Failures in auditing;
- Economic pressures compromising safety;
- Failures in regulatory oversight and inspection;
- Workers and others expressing concerns prior to incident;
- Poor management – worker communication and trust; and
- Emergency and rescue resources and procedures" (Quinlan, 2014; Quinlan, 2016).

These pattern causes identified by Quinlan (2014) appear to take a step back from the trigger events associated with the fatalities and instead focused on the root causes responsible for the fatalities occurring. This approach would be highly effective in identifying areas in SHMS that require additional due care to prevent fatalities. However, determining the categorisation of historical fatalities based on the root causes could be problematic due to a lack of available information. Establishing the root cause that led to a fatality in addition to the trigger event could provide significantly important information to the mining industry if the information were available.

The causal factors identified in the reports, books and articles discussed above were collated and disclosed in Table 8 along with the reference sources for each category.

When examining Table 8, it becomes apparent that there are multiple ways of categorising the causes of mining fatalities. Electrocution, ground fall, inrush and fire were all referenced five or more times. Additionally, Joy (2004) recommends the use of energy sources while Quinlan (2014) suggests ten root causes in terms of control failures.

The available literature seems to indicate that while there is not one single, most effective method for analysing mine fatalities, each fatality can be assessed from at least three different perspectives. The first perspective is the most primary, focussing on the form of uncontrolled energy that was released when the fatality occurred; this method can classify the majority of fatalities into one of nine categories listed by Joy (2004). The second perspective involves categorising fatalities according to the mechanism that embodied the energy source or the trigger event leading to the fatality. This perspective can become very broad and includes the causes identified in Table 8. The third perspective of analysis follows Quinlan's root cause approach and requires that the failed control measure or the absence of a control measure be used to classify the fatality. Quinlan (2014) states that this can be done for the majority of cases by considering ten different patterns that lead to fatalities.

Each method of fatality categorisation has its own benefits and difficulties. Perspective one could be useful in determining where risk assessments failed to identify potentially fatal hazards. Perspective two allows mines to identify high risk areas that have inadequate controls and are often involved in fatal incidents. Perspective two is most likely the easiest perspective to communicate to the workforce. The third perspective is very useful in determining where management or certain control measures might have failed to prevent a fatality.

Perspectives one and two will be extensively used to identify fatality causes in this report. The categories identified by these perspectives that indicate the highest potential for resulting in fatalities will then be examined more extensively from the third perspective to establish where control measures or management might have failed in preventing the fatalities.

2.5.1 Equipment Related Fatalities

The use of mining equipment offers mining companies various benefits, such as improving work efficiency and effectiveness, reducing the requirement for the manual operation of tasks and increasing the amount of production achievable (Horberry, 2011). Effectively every mining operation in Queensland and Australia incorporates the use of some form of equipment and mining equipment is continuously evolving, often introducing new hazards to the industry. Joy (2004) notes that when mining technology changes, it often involves major hazards. It is therefore no surprise that equipment related fatalities represent a significant contribution to industrial scale fatalities.

Burgess-Limerick and Steiner (2006) state that mining equipment operated and maintained on site have considerable and diverse energies associated with them. The authors warn that a loss of control over these energies commonly result in injuries or fatalities to mine workers. Annual deaths involving workplace machinery, appliances, tools and equipment exceed 200 fatalities per annum on average (Horberry, 2011).

Collisions involving large mobile equipment are still common occurrences within the mining industry. Additionally, vehicle interactions and incidents involving pedestrian and vehicle interactions are significant contributors to Australian mining fatalities, comprising 35 % and 53 % of national fatalities respectively despite the increasing reliance on proximity warning and collision detection systems.

Equipment collisions are not only detrimental due to their contributions to mining fatalities but also pose significant financial costs to companies due to the repair requirements and lost production (Horberry, 2011).

The mining industry constantly requires new mining equipment to increase productivity by being larger, operating faster and having increased power capabilities. These requirements lead to a complex balancing of safety performance with productivity requirements, often leading to increases in the likelihood and severity of associated injuries and fatalities (Horberry, 2011).

Zhang, Kecojevic and Komljenovic (2014) established that 21.6 % of mining equipment related fatalities in the United States (US) resulted from haul truck incidents. The authors analysed their data by assessing possible correlations with the victims' age and experience as well as investigating the possible influences of the location of the haul trucks and the activity they were conducting at the time of the fatalities. It was found that haul trucks moving forward on haul roads were responsible for the most fatalities at surface mining operations in the US. Zhang, Kecojevic and Komljenovic also assessed the incidents to determine the root cause of each incident. The root causes identified by the study are represented in Figure 6.

Root cause summary.

No.	Root cause	Frequency
1	Inadequate or improper pre-operational check	6
2	Poor maintenance	4
3	Inadequate training	2
4	Excessive speed	1
5	Established rule, policies for moving/approaching large mobile equipment was not followed	1
6	Operator experiencing brake or control problems	1
7	Automatic slack adjusters were readjusted manually	1
8	Inadequate procedure to detect the driver who was not fit for service	1
9	The driver's blood alcohol/ethanol level was 0.08% while operating heavy equipment	1
10	No seat belts provided	1
11	No properly operating door latches for either side of the truck	1
12	No audible warning device for low air pressure	1
13	Air pressure gauge needles (green and orange) that measure the primary and secondary air braking system pressure were plumbed backwards	1
14	Air pressure gauge that measures the primary and secondary air braking system was reading 15–20 psi higher than actual pressure	1
15	No tachometer or speedometer	1
16	The truck was not equipped with adequate brakes	1
17	The driver was not instructed to test the brake system	1
18	The truck missed the berm	1

Figure 6**.** Table of root causes for haul truck related incidents at mines in the United States (Zhang, Kecojevic and Komljenovic, 2014).

Mining fatality literature seems to be dominated by fatalities related to mining equipment. As mining has become more mechanised over the years, it would seem that mining equipment has become one of the primary sources of fatalities on mine sites.

The literature seems to indicate that haul trucks are the main perpetrators when it comes to mine fatalities however it should be analysed within the inherent limitations that most studies considered coal mines and the majority of literature assessing correlations between mining equipment and mine site fatalities considers data obtain from mines in the United States.

In order to assess whether the hazards identified by the various authors related to mining equipment usage are applicable to Queensland's metalliferous mines, a thorough analysis focussing specifically on the involvement of equipment in the fatalities at Queensland mine sites will be undertaken.

3 FATALITY DATA ANALYSIS

3.1 DATA COLLECTION AND DATABASE CREATION

This project is based on a thorough analysis of data pertaining to metalliferous mining and quarrying fatalities in Queensland. Before any meaningful analysis could be performed, substantial amounts of supplementary data in addition to the primary data base utilised had to be obtained.

In order to analyse the fatalities within context and to consider the contributing factors and the circumstances surrounding the incidents, mining warden inquiry reports were used to investigate the fatalities from 1986 to 2001. Warden inquiry reports for fatalities post 2001 could not be obtained and therefore a range of alternative supplementing sources of information were used to study the fatalities in more detail.

A database of information that lists various parameters relating to the fatalities that occurred from 1986 to 2016 was subsequently created, Appendix A.

3.2 ANALYSIS DIFFICULTIES

This analysis investigated two particular periods of fatality data. The period from 1879 to 2016 included the entire fatality record available at the time of writing. This period was analysed for overall trends and to assess the limited number of parameters that were available for all the fatalities.

Performing a detailed statistical analyse on the entire dataset for this period would be extremely difficult due to the fact that detailed information related to the fatalities is not publicly available. Even news articles for fatalities prior to 1989 are very difficult to find.

An additional issue to consider is the relevance of the data to the modern industry. It is highly likely that fatalities that occurred in the 1800s were subject to overwhelmingly different safety management, legislation and differing best practice environments. It was therefore assumed that the more recent fatalities would represent the best indicators of current issues within the industry that would urgently need to be addressed.

Considering the abovementioned factors, fatality data encompassing 1986 to 2016, which relates to 15 years prior to and 15 years post the implementation of the Mining and Quarrying Health and Safety Act 1999 (QLD) was analysed in depth to determine the most relevant issues still contributing to industry fatalities in the current safety environment.

During this 30-year period there were 62 fatalities that occurred. Due to the small sample size and the nature of the sample data, meaningful, traditional statistical analysis was not possible on such a small sample. The destructive nature of the sample data also meant that it was impossible to obtain more sample points. The nature of the sample data meant that insufficient data was a good indication as it points to fewer fatalities.

3.3 ANALYSIS METHODOLOGY

The data was analysed to identify trends and clusters of data that displayed common hazards, causation factors and critical activities related to the fatalities. This approach was successfully employed by the Western Australian Department of Mines and Petroleum (2014) on a smaller sample size than the 62 fatalities being investigated for the purposes of this report.

The fatalities were investigated to consider the effects of over 21 parameters, identified in Section 1.4 of this report, in order to identify the focus areas where improvements in mining safety might be required. A lack of available information made it impossible to assess the effects of certain parameters on the fatalities within Queensland’s metalliferous mining industry, however additional contributing factors were discovered during the analysis process.

4 RESULTS AND DISCUSSION

4.1 EMPLOYMENT AND ANNUAL FATALITY RATES

Annual total employment and total fatality rates are characteristics for which data is available dating back to 1879. The analysis commenced with an investigation of the relationship between the number of individuals employed annually within Queensland's metalliferous mining and quarrying industry and the number of fatalities that occurred annually within the industry. This is illustrated in Figure 7, on the next page, for the period encompassing 1879 to 2016.

Upon visual inspection, it becomes apparent that from 1879 to approximately 1964, the total annual fatalities represented by the blue line seems to fluctuate with the level of annual employment in the industry represented by the orange bars. The statistical correlation for the period from 1879 to 1964 was calculated to be 77.36 % while the standard deviation for the annual total fatalities over the same period was calculated to be 7.68 fatalities. It would seem that during this period the number of fatalities within the industry were heavily related to the number of individuals employed within the industry. Since numerically every employee in the industry has a probability to potentially be involved in a fatal accident, it is up to the implementation of legislation and risk management processes to reduce that inherent probability. The substantial correlation prior to the 1964 Act in Figure 7 however seems to point towards poor risk mitigation and safety performance during this period.

The solid red line on Figure 7 indicates the implementation of the Mines Regulation Act 1964 (QLD). The timing of the implementation of this act seems to correspond to a very important change in the relationship between the annual employment levels and total fatality rates within the industry. Post the implementation of the Act, the correlation between the level of employment and fatality rate noticeably decreases, highlighted in the graph by the fact that the trend of the annual total fatalities, indicated by the red dotted line, continues to decrease after the implementation of the 1964 Act despite the level of employment fluctuating and even increasing over the same period. This would seem to indicate that the metalliferous industry's safety performance improved substantially after the implementation of the Mines Regulation Act 1964 (QLD).

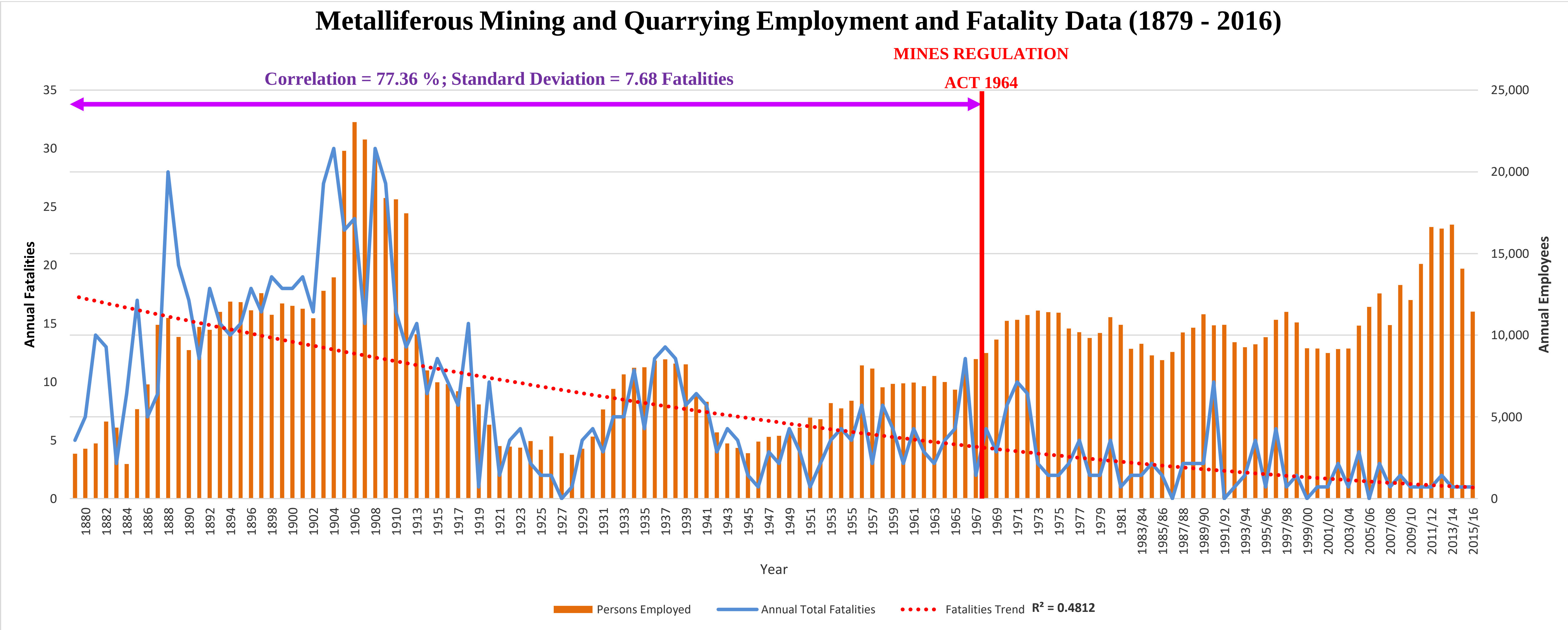

Figure 7. Relationship between annual fatalities and annual level of employment.

To investigate whether the implementation of the current risk-management based legislation might have had a similar positive influence on the safety performance of the industry, the relationship between industry employment levels and fatality occurrence rates was re-examined by focussing the analysis on the 30-year period encompassing 1986 to 2016. Figure 8, on the following pages, was created to illustrate the relationship between the annual fatalities in the industry and the annual level of employment from 1986 to 2016.

Examining the graph in Figure 8, it becomes evident that the trendline representing the annual fatalities continues to decline over the 30-year period and seems to reach a plateau at a single fatality per year in the most recent years. An important observation is made however when the period prior to the implementation of the 1999 Act is compared to the period post the implementation of the Act. The standard deviation of the total annual fatalities decreases from 2.58 fatalities prior to the Act to 1.06 fatalities post the Act.

The decrease in the standard deviation of fatalities coincides with the timing of the 1999 Act's implementation in 2001. This seems to indicate that not only has the risk management based legislation positively impacted the industry by continuing the decline in annual fatalities, shown by the trendline, but additionally it seems to have also substantially decreased the amount of variation in the total annual fatalities that occurred within the industry. It should be noted that the decreasing trendline and variation of annual fatalities is observed over a period of time when the level of employment in the industry continues to fluctuate and even has a noticeable spike during 2010-2015.

Focussing on the relationship between employment and fatalities for most recent years, spanning 2007 to 2016, the annual fatality occurrence seems to have reached a plateau in terms of improvement. Averaging a single fatality a year is an admirable achievement for the industry but it still eludes the goal of zero fatalities. The plateauing effect is confirmed by Figure 9 which shows the cumulative fatalities for the industry from 1877 to 2016 and by Figure 10 which illustrates the normalised fatality rate per 1000 employees from 1879 to 2016. Both Figures 8 and 9 indicate that improvements in the annual fatality rates have reached a plateau at a single fatality per year.

To consider how the plateau described above might be breached to further improve the safety performance of the industry, it is useful to consider what has occurred historically and to learn from these events and processes. In the late 1960s, the safety performance of mines in the UK had reached a similar, albeit higher value, plateau in fatality occurrence under the then prescriptive safety legislation. This prompted the commissioning of the Robens report which suggested that the prescriptive legislation be replaced with risk-management based legislation. It was this progressive approach to safety improvement that breached the fatality plateau and substantially improved the safety performance of the industry. Queensland’s metalliferous mining industry seems to have reached another plateau in fatality occurrence rates and a new progressive strategy is now required to progress the industry even closer to the ultimate goal of zero fatalities.

An important consideration to bear in mind for this analysis is that correlation does not necessarily indicate causation and therefore the decreases in fatality trends and variations, while seemingly perfectly coinciding with the implementation of the various Acts, might be attributable to other factors that are less obvious and observable. The alignment of the timing of these changes with the implementation of the highlighted Acts provides a strong argument that the legislation has indeed been effective in achieving improved fatality performance both in terms of occurrence and variation.

It should also be noted that for this analysis, no employment data was available for the years 1877, 1878 and 1912. Subsequently these years were omitted from all analysis except for Figure 9 which illustrated cumulative fatality data.

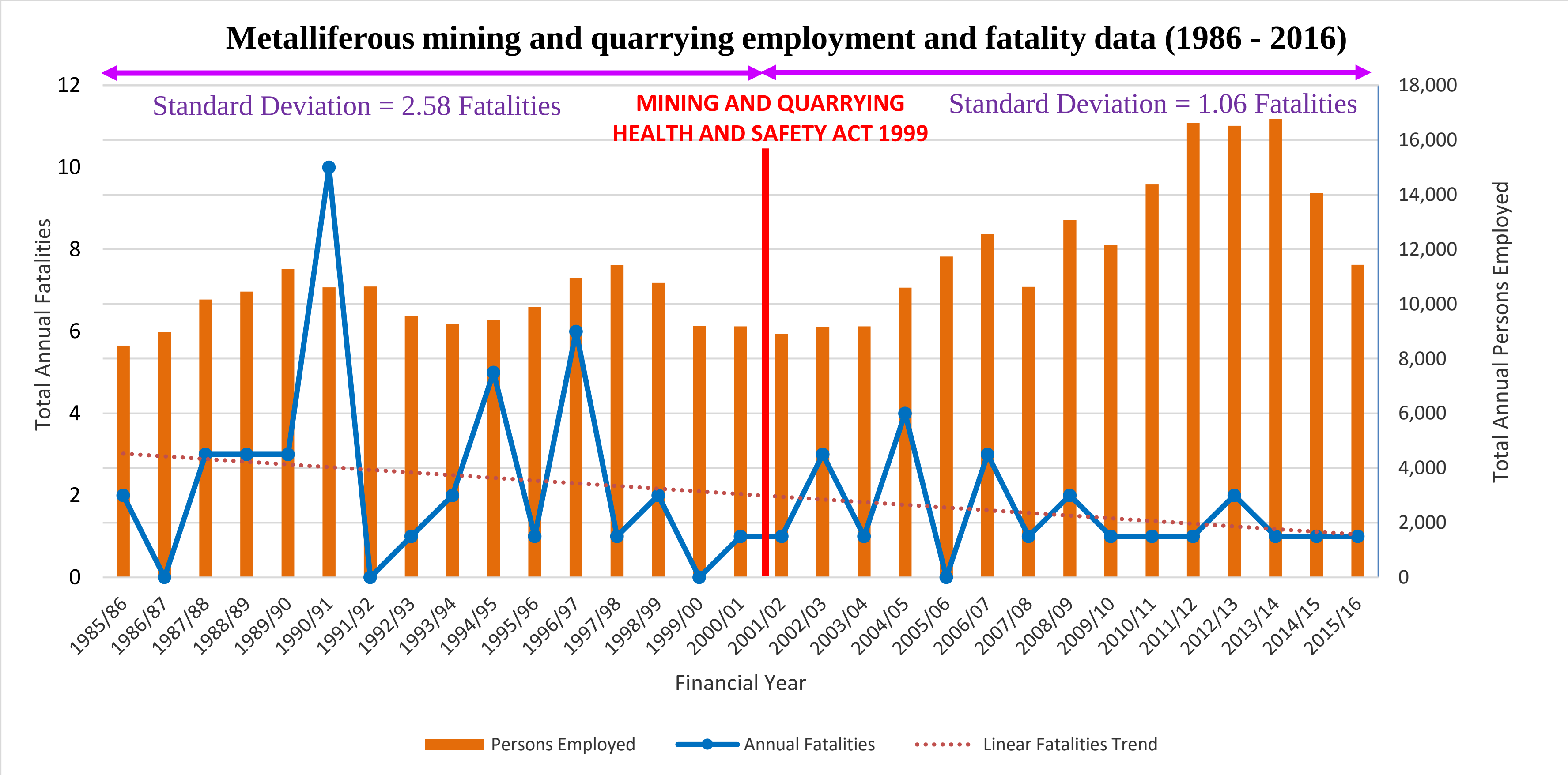

Figure 8. Relationship between annual fatalities and annual level of employment for 1986 to 2016.

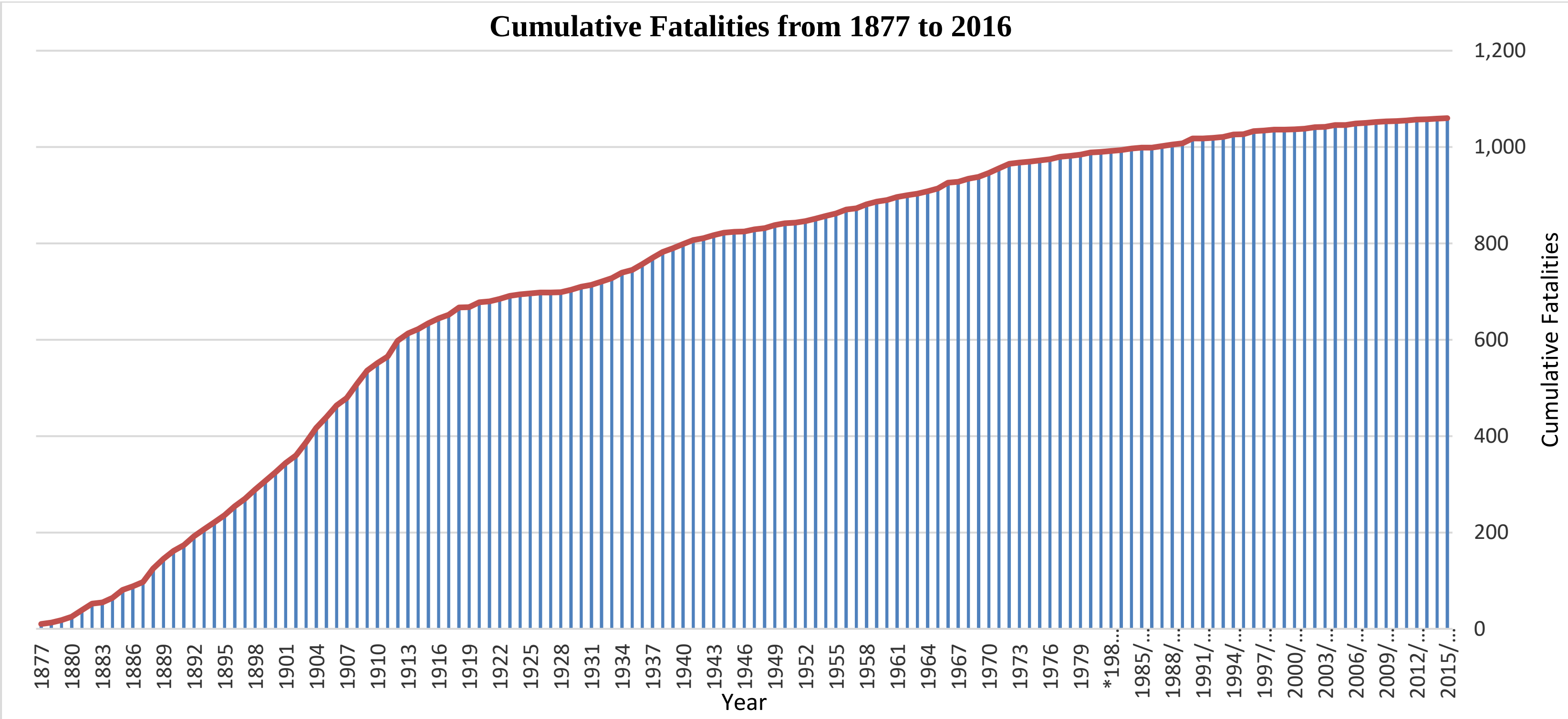

Figure 9. Cumulative amount of fatalities from 1877 to 2016.

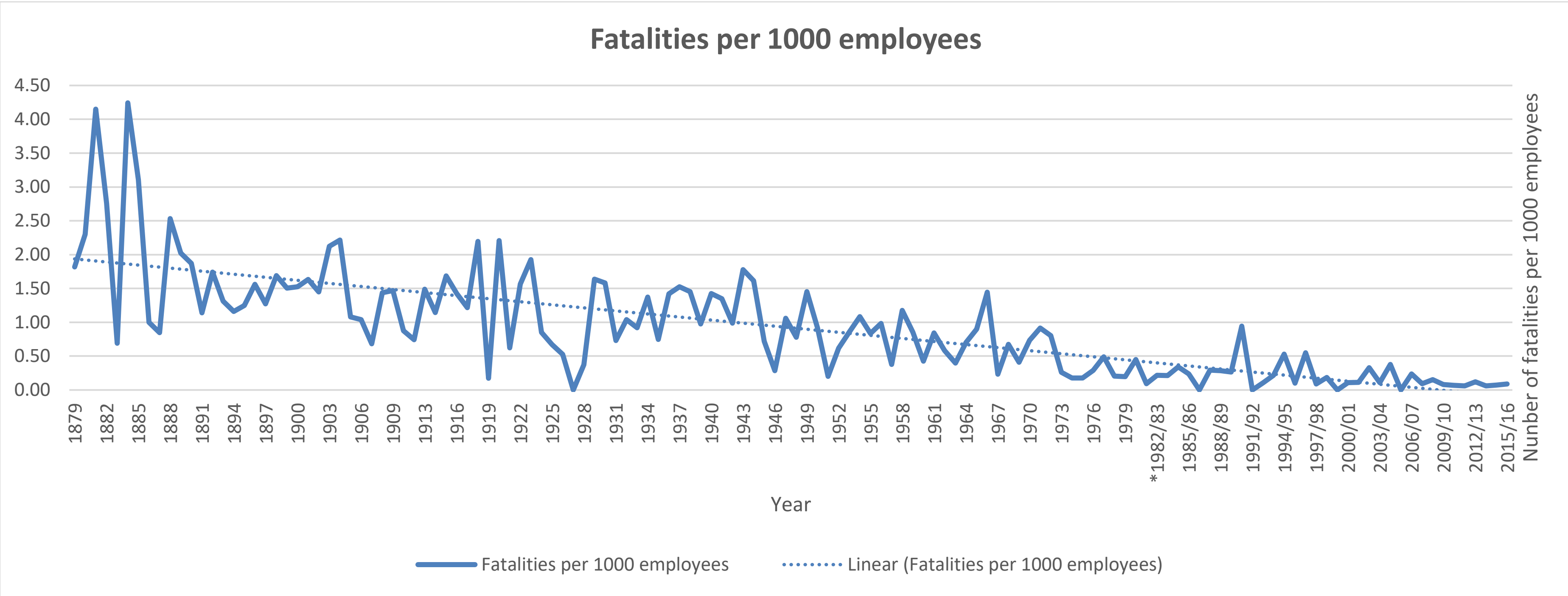

Figure 10. Normalised annual fatalities per 1000 employees for 1879 to 2016.

Additional, simple descriptive statistics for the annual level of employment and the annual number of fatalities within the industry are contained in Table 7.

Table 7
Descriptive Statistics of employment and fatality data for 1879 to 2016.

	1879-1964	***1964-2016***	***1986 - 2001***	***2001 - 2016***	***Total***
Average Fatalities	10.06	2.98	2.41	1.53	
Average Employees	7,933	10,730	9,951	12,518	
Max Annual Fatality	30	12	10	4	
Amount of Zero Fatality Years	1	4	3	1	5

The date groupings of the information contained in Table 7 were selected to emphasize the potential influences of the Mines Regulation Act of 1964 (QLD) and the Mining and Quarrying Safety and Health Act 1999 (QLD).

From the information in the table it should be noted that the average amount of annual fatalities decreased from 10.06 before the Mines Regulation Act 1964 (QLD) to 2.98 after the Mines Regulation Act (QLD) despite average employment levels increasing from 7933 to 10730 employees over the same time period. A similar result was observed for the Mining and Quarrying Safety and Health Act 1999 (QLD) with average annual fatalities decreasing from 2.41 to 1.53 per year prior to and post the implementation of the Act despite annual employment levels increasing from 9951 to 12518 employees over the same time period.

The maximum amount of fatalities to occur within a single year also decreased from 30 prior to the Mines Regulation Act to 12 post the Act and a decrease from 10 fatalities in a single year prior to the 1999 Act’s implementation to 4 post the implementation is observed.

These statistics seem to strengthen the argument that the implementation of these Acts have had profound impacts on the safety performance of the industry and are very likely the reason for the improvements noted in the fatality trends and variation too.

The requirement for further improvements to the industry's safety performance is justified by the observation that over 137 years there have only been 5 years where no fatalities were experienced.

Employment numbers over the period increased from 8476 in 1986 to 11438 employees in 2016. That equates to a 34.95 % increase in the number of people employed in the industry although it should be noted that during the 2010 to 2015 period the industry saw a spike in employment reaching a maximum of 16765 employed persons in 2013/2014.

4.2 WORKPLACE CHARACTERISTICS

4.2.1 Commodity

Figure 11 illustrates the number of fatalities that occurred within the industry, classified by the commodity that was being mined when the fatality occurred. From the chart, it can be seen that the commodities copper-gold and zinc-lead-silver were the largest contributors to the fatalities that occurred during the period. To establish the potential reasons why so many fatalities occurred while mining these commodities, it is necessary to consider whether the majority of the fatalities occurred at different mine sites or at the same mine site. This is explored in the next section.

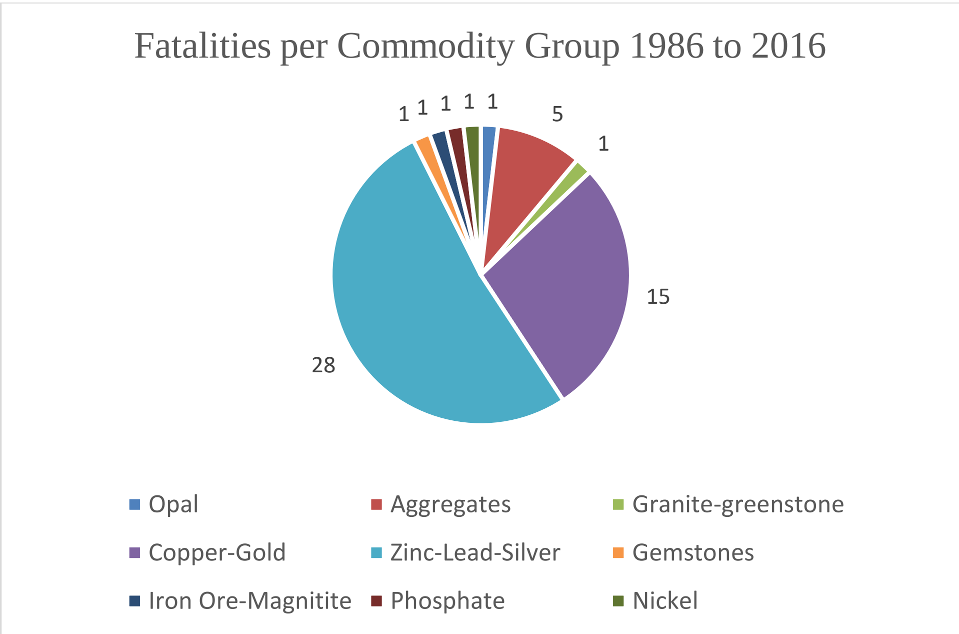

Figure 11. Fatalities for Different Commodities 1986 to 2016.

4.2.2 Mine Site

After considering the fact that most fatalities seem to be related to the mining of copper-gold and zinc-lead-silver ore bodies, the fatalities were assessed to determine at which mine sites they occurred. This helped determine whether the frequently occurring fatalities classified in Figure 11 were attributable solely to the type of commodity being mined or whether site performance played a more important role in determining the cause of these fatalities.

Figure 12 illustrates the number of fatalities that occurred at each metalliferous mine site over the 30-year period from 1986 to 2016. Examining the graph, it is clear that the majority of mine sites had contributed only a single fatality over the 30-year period. There are however six sites namely: Cannington, Mount Isa, Highway-Reward, Cracow, EPM-Cloncurry and Tick Hill that were responsible for more than a single fatality each. Mount Isa in particular had seen 21 fatal accidents occur at its operation over the 30-year period.

The sheer scale of the operation at Mount Isa is a possible explanation for the rate of fatalities. Another possible influencing factor is the fact that the Mount Isa operation includes concentrators and smelters that present additional hazards and accounted for 6 of the 21 fatalities that occurred at the site. It is concerning that over the 30-year period analysed, certain accident were repeated multiple times at the Mount Isa operations.

Section 4.5.2 of this report discusses equipment related fatalities and highlights that no less than four loaders have fallen into open stopes resulting in four fatalities over the period from 1986 to 2016. Three of the loader incidents occurred at the Mount Isa operation with the fourth occurring at the Mount Isa owned George Fisher mine. There can be various reasons for the fact that these incidents were repeated and the specific circumstances surrounding each incident were slightly different however this statistic reinforces the importance that should be placed on learning from incidents and improving site controls and processes in a timely manner to prevent the recurrence of fatalities.

It is difficult to determine whether the change in ownership resulting from Mount Isa Mines being acquired by Xstrata and then by Glencore had resulted in improvements to the site's health and safety management system but it would non the less benefit the site to rapidly update and evolve their SHMS when fatalities occur to ensure every effort is made to reduce fatalities at the site.

The fatalities related to the mining of copper-gold ore bodies are spread across multiple sites and seem to indicate that the influencing factor is more likely the multitude of copper-gold mines operating in Queensland rather than the fault of a particular site.

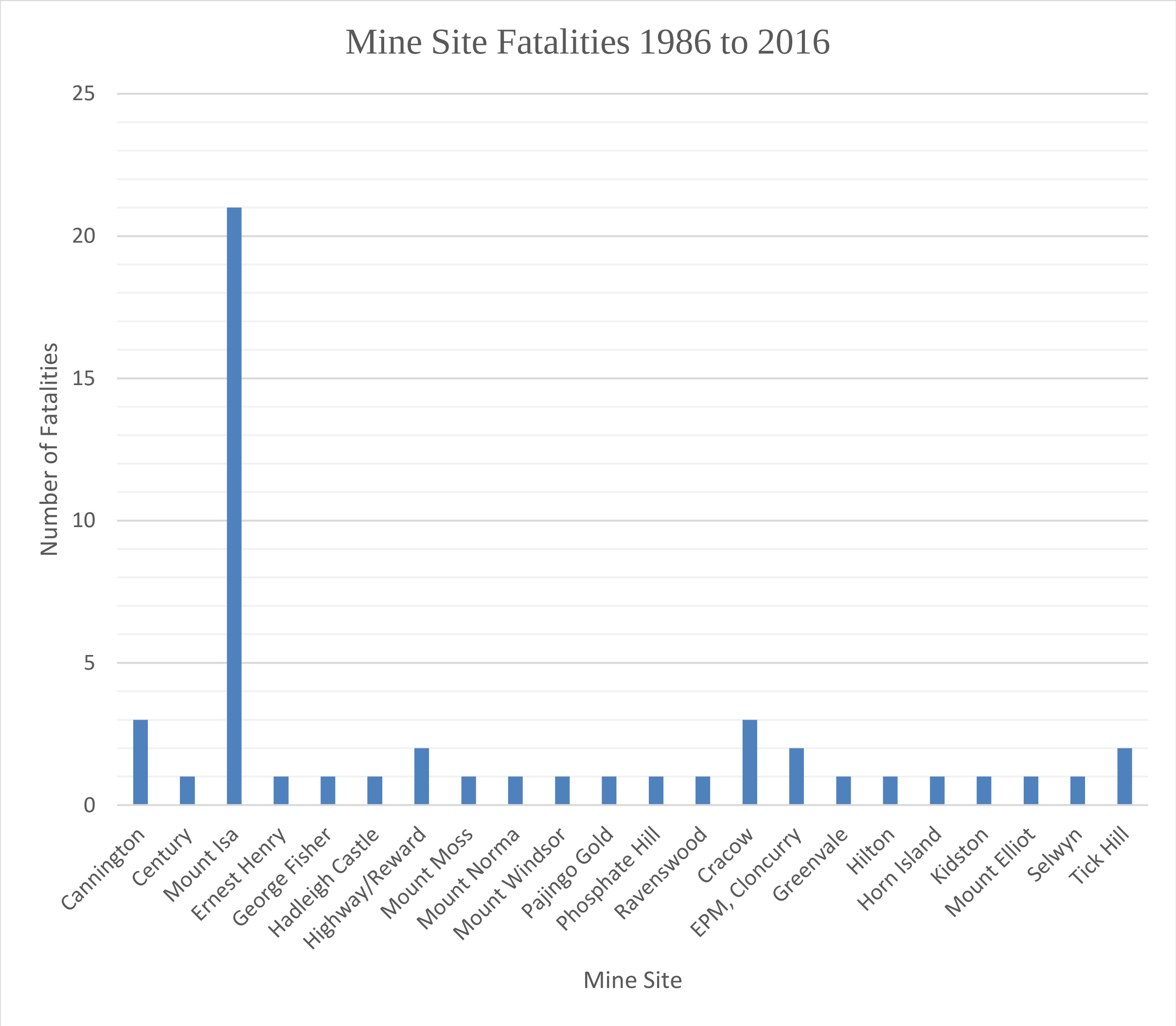

Figure 12. Fatalities at Different Mine Sites in Queensland.

Apart from the metalliferous mines, there were also three fatalities at opal mines and a single fatality at a gemstone mine/tourist mine. These fatalities are related to the fossicking nature of these operation and therefore do not relate to the data contained in this analysis in any substantial manner.

Queensland also experienced six quarry related fatalities from 1986 to 2016 that occurred at the following sites:

- Bracalba Quarry;
- Roseneath Quarry;
- Wongabel Quarry;
- Castle Creek Quarry;
- Tichum Creek Quarry; and
- Moranbah South Quarry.

The causes of the fatalities that occurred at the quarries did however not indicate any substantial data concentrations nor common causes that could be analysed for such a small sample.

Two fatal incidents that occurred during exploration activities were excluded due to being related to an aircraft accident.

4.2.3 Surface vs Underground

Figure 13 illustrates a comparison of fatalities that occurred on the surface vs fatalities that occurred underground for the period encompassing 1986 to 2016.

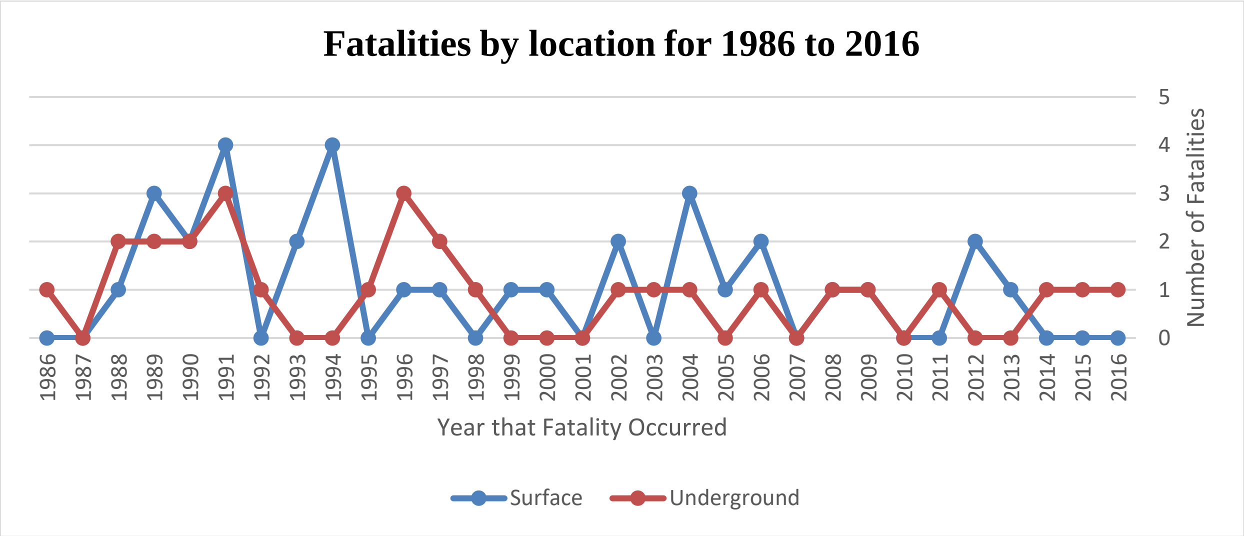

Figure 13. Number of fatalities by location from 1986 to 2016.

With the exception of the surface fatality quantities showing slightly more fluctuations and variation than the underground fatality quantities, there does not seem to be any other discernible patterns inherent in the fatality location data in Figure 13.

Of the 62 fatal accidents, 28 were underground and 34 were surface based. Over the period, there were approximately 9 % more employees working at surface operations compared to underground operations. Even when the fatality data had been normalised with employee statistics, surface fatality incidents were still 1.1 times or 10 % more likely to occur than underground fatalities.

The most likely explanation for the higher observed surface fatality rates is that the surface fatality data includes fatal accidents that occurred in processing plants, smelters and during exploration activities in addition to the fatalities that occurred during the extraction and development of the mine itself. It can therefore not conclusively be said that surface metalliferous mining should be considered to be more dangerous than underground metalliferous mining but it should be noted that the safety performance of modern underground mines no longer seems to lag behind that of surface mining operations.

4.3 TIMING CHARACTERISTICS

4.3.1 Day of the Week

Figure 14 illustrates the days of the week that fatalities are most likely to occur based on the historical frequencies observed from 1986 to 2016.

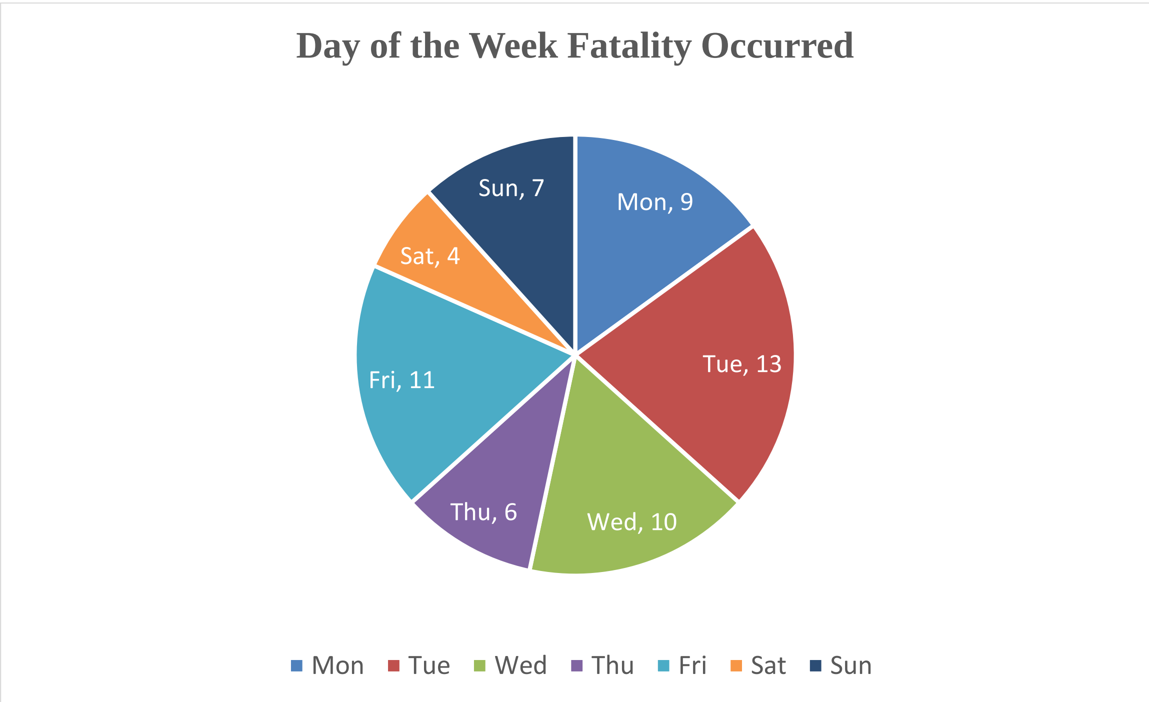

Figure 14. Fatalities for day of the week.

Figure 14 indicates that fatalities are most likely to occur on Tuesday or Wednesday, mid-week, and on Fridays, right before the weekend. A possible reason for the trends observed could be the fatigue and mental state of the employees. Employees might have a harder time concentrating mid-week as they are slightly fatigued from a few days' work and their mental state might be affected by the knowledge that they still have a few days to go before the end of their rosters are reached. The high incidence rates on Fridays could possibly indicate a lack of focus due to employees' mental conditioning to normally look forward to the weekend instead of maintaining all their focus on the task at hand.

It is important to note however that the interpretation of the frequency of fatalities for specific days of the week will depend on the rosters and hours worked by employees.

The time of day that fatalities occurred was also assessed but no observable trends nor clusters in the data relating to incident timing or day shift vs night shift were discovered.

4.4 EMPLOYEE FACTORS

4.4.1 Gender and Age of Deceased

All incidents except for one involved males. The female accident was a female visitor who had been drinking at a hotel before her site visit and subsequently had a blood alcohol reading of 0.086 gm/100 ml. She got out of the road-train in which she had travelled to the site, accompanying the driver, and proceeded to lie down next to it to "look at the stars". The loader that was loading the truck subsequently drove over her (Kennedy, 2006).

The age of the deceased individuals demonstrated no noticeable trends.

4.4.2 Occupation of the Deceased

Figure 15 illustrates the fatalities that occurred in the industry, categorised according to the occupation of the deceased individuals. Equipment operators represent the occupation that is most prone to the occurrence of fatalities. This is unsurprisingly due to the energy sources related to the operated equipment as well as the fact that mining equipment often operate in the most high-risk areas of a mine site.

Manual trades represented the second largest portion of fatalities and involved boilermakers, fitters, shunters, timbermen, etc.

The 'other' category involved a safety advisor, pilot, miners, unknown, visitor, etc.

Two incidents involving children were excluded from the data before the pie-chart was generated. The one child died as a result of a fire that engulfed a caretaker’s residence at the Bracalba Quarry while the other one was fatally injured when he was struck by a rock that fell from an excavation face while he was fossicking at the Mount Hay Tourist Mine (Devine, 2017).

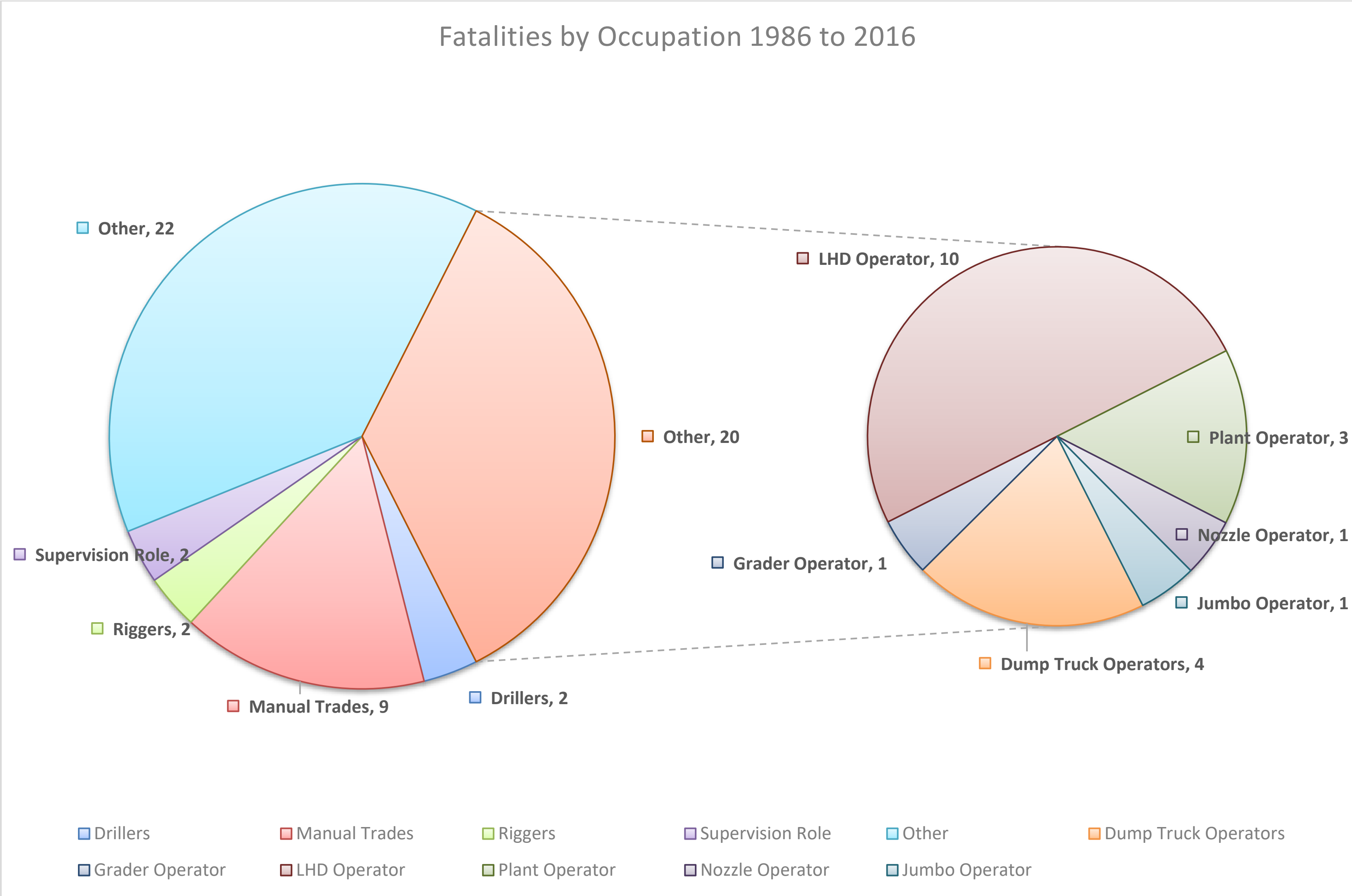

Figure 15. Fatality by occupation 1986 to 2016.

4.4.3 Contractor Involvement

Nelson (2017) wrote a comprehensive report analysing the involvement of contractors in fatalities that occur in the industry. Nelson discovered that contractors were more likely to be involved in fatal accidents and the most likely reasons for this seems to be the fact that contractors are often employed to perform very difficult and dangerous tasks on mine sites. Additionally, contractors that transfer between sites often do not obtain an in-depth understanding and appreciation for the Safety and Health Management System that is employed at the local mine sites.

Nelson's comprehensive study of contractor involvement in mining fatalities meant that no new patterns or contributing causes were identified during this study.

4.5 OTHER FACTORS

4.5.1 Hazardous Energy Sources

Section 2.5 of this report described how all fatal accidents can be attributed to a source of uncontrolled energy. Devine (2017) classified all the fatal accidents that occurred in Queensland's metalliferous mining and quarrying industry from 1877 to 2016 according to the source of uncontrolled energy released that ultimately resulted in the fatal accident. Figure 16 summarises the fatal accidents related energy sources for the period encompassing 1917 to 2016 (Devine, 2017).

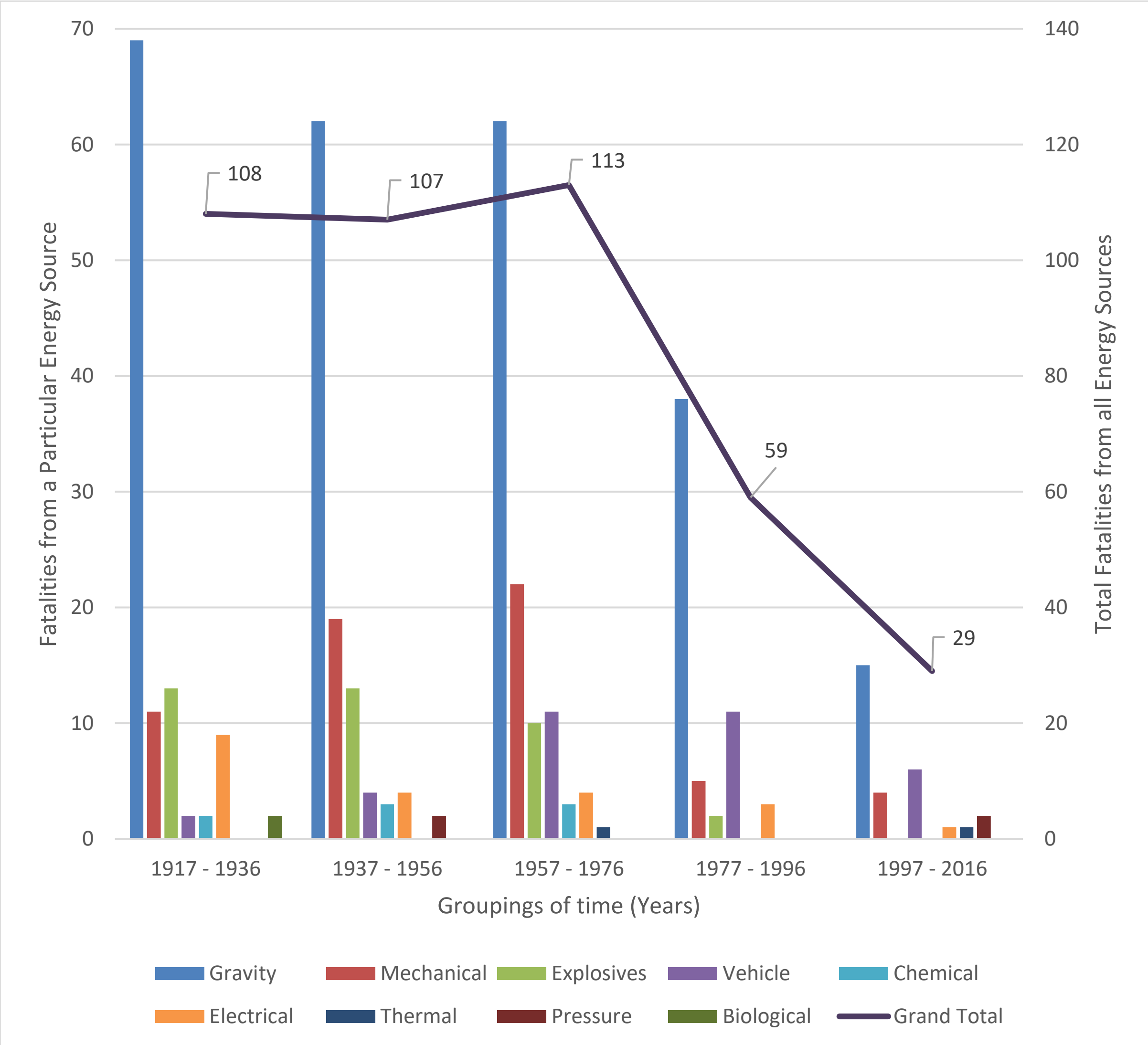

Figure 16. Fatalities classified by source of uncontrolled release of energy 1917 to 2016 (Devine, 2017).

Figure 16 indicates that gravitational potential energy has posed the greatest risks to employees on mine sites since the early 1900s. Some hazardous energy sources, such as explosive and chemical energy, are very well controlled in modern mining environments and as a result they rarely result in fatalities anymore. Explosives are now subject to the Explosives Act 1999 (QLD) which might explain the substantial improvements in the explosives' safety performance observed in modern mining. Increases in the scale of mines have however resulted in large quantities of vehicles that are required to drive longer distances and interact with larger machinery on sites. It is therefore not surprising to note that vehicle related fatalities increased since the early 1900s.

Figure 17 classifies the fatal accidents that occurred over the 30-year period from 1986 to 2016 according to the source of uncontrolled energy released. Gravity continues to present the greatest source of hazardous energy on site even today, examples of how it influences substantial amounts of fatalities will be explored in the sections to follow. After gravity, both mechanical and vehicle related energies were the largest contributors to recent fatalities.

Modern mines are very large in scale and highly mechanised which results in multiple mechanical and vehicle related energy sources that require adequate controls to be put in place. The large quantities of equipment on site and the interactions between these pieces of equipment and employees are major contributors to these statistics and are discussed in detail in Section 4.5.2.

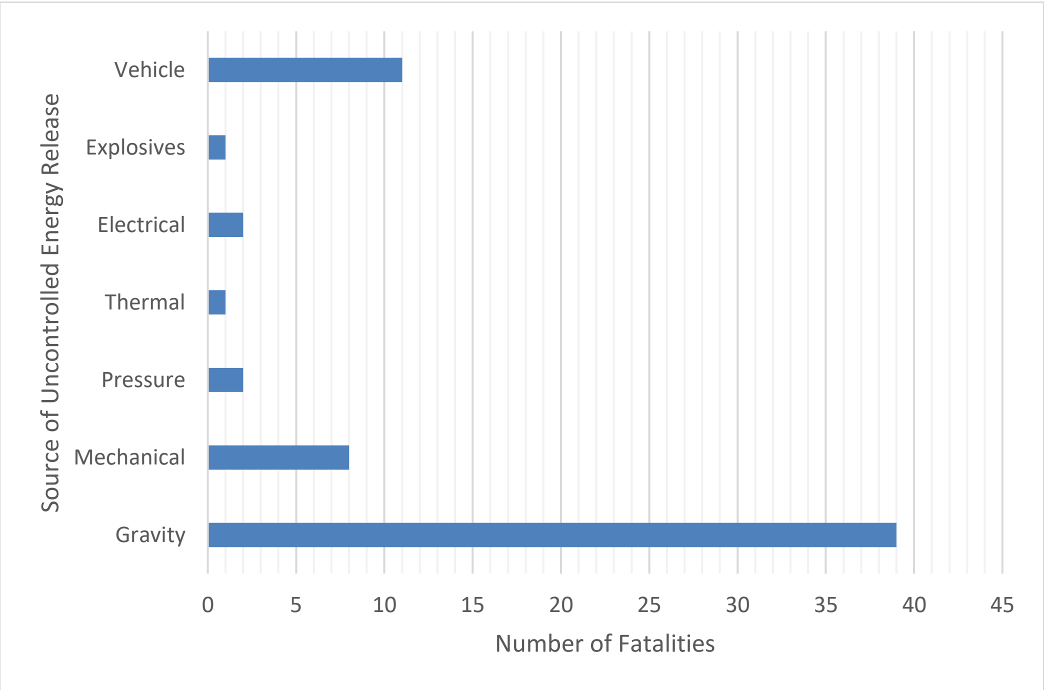

Figure 17. Fatalities resulting from uncontrolled energy releases 1986 to 2016.

Assessing the fatality data for safety performance improvements from 1986 to 2016, the data for the fatalities that occurred from 2002 to 2016 had to be normalised to determine whether improvements in controlling specific energy sources were achieved with the implementation of risk-management based legislation. Since 39 fatalities occurred from 1986 to 2001 and only 25 occurred from 2002 to 2016, fatality data for each energy category within the 2002-2016 range was multiplied by a normalising factor of 1.56. This factor represents the ratio of total fatalities during 1986-2001 divided by total fatalities during 2002-2016.

Figure 18 illustrates the normalised fatality data categorised according to the period of time in which they occurred. Examining Figure 18, it seems that gravity related fatalities continues to decrease while vehicle related fatalities are increasing and mechanical energy related fatalities remain approximately constant. The data would therefore seem to suggest that a concerted effort needs to be made by the industry to introduce more effective controls that prevent fatalities related to the uncontrolled release of energy from vehicles from recurring.

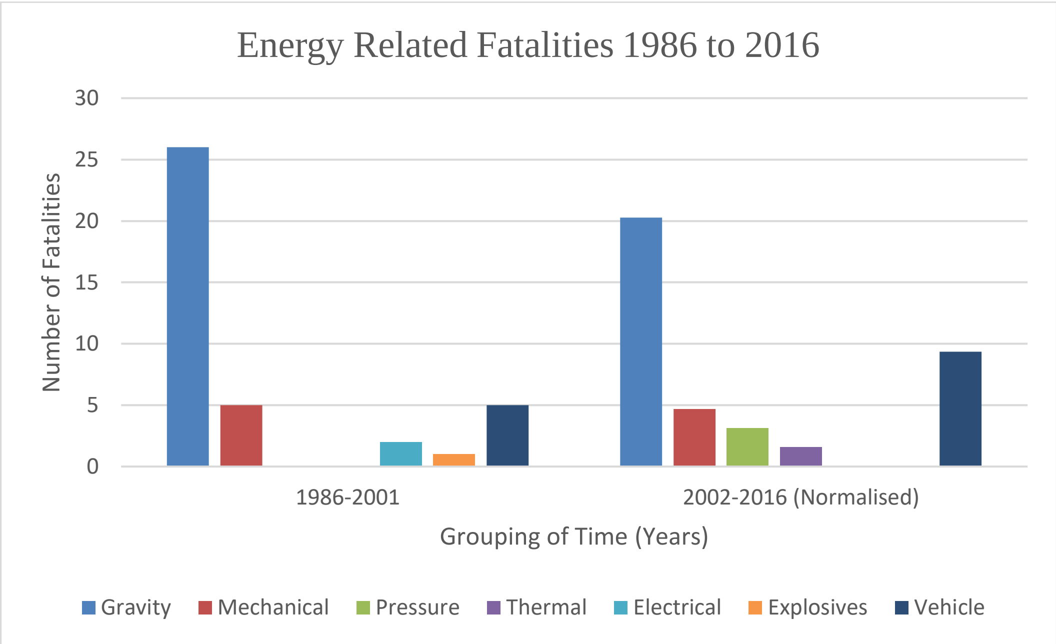

Figure 18. Fatalities resulting from uncontrolled energy releases 1986 to 2016.

4.5.2 Equipment Involvement

Consistent with the results in Sections 4.4.2 and 4.5.1, it was determined that for the 30-year period from 1986 to 2016 equipment was involved in 27 of the 62 fatalities or 43.6 % of all the fatalities that occurred in the metalliferous mines and quarrying industry. Although a variety of different equipment were involved, the piece of equipment most frequently involved were loaders. Loader related fatalities comprised 13 of the 27 equipment related fatalities or 48 % of all equipment related fatalities in the industry.

In an attempt to uncover why loaders are involved in so many fatalities, the main causes of the fatalities are illustrated in Figure 19. The fatal causes include being crushed by a section of the loader, the loader overturning, the loader driving and falling into an open stope and collisions with pedestrians. Collisions with pedestrians was found to be the highest cause resulting in loader related fatalities while loaders overturning was determined to be the lowest cause of loader related fatalities.

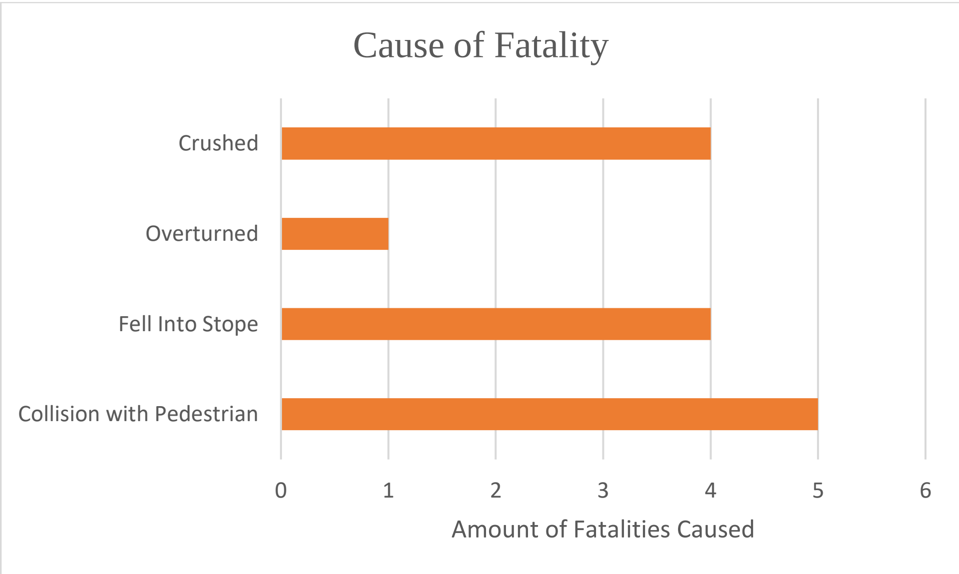

Figure 19. Main causes of loader related fatalities.

A possible reason for the large number of fatalities resulting from collisions of loaders with pedestrians can be deducted from Figure 20. Figure 20 illustrates the main factors that contributed to loader related fatalities according to the investigation reports contained in the warden inquiry report (2014). Insufficient visibility, poor lighting, inadequate communication, inadequate signage and inadequate underground markings all contribute to impeding the awareness of the loader operators while performing their tasks. With the operators' awareness of the surroundings in which they operate being obstructed, the presence of pedestrians in that environment adds all the elements required for fatalities to occur.

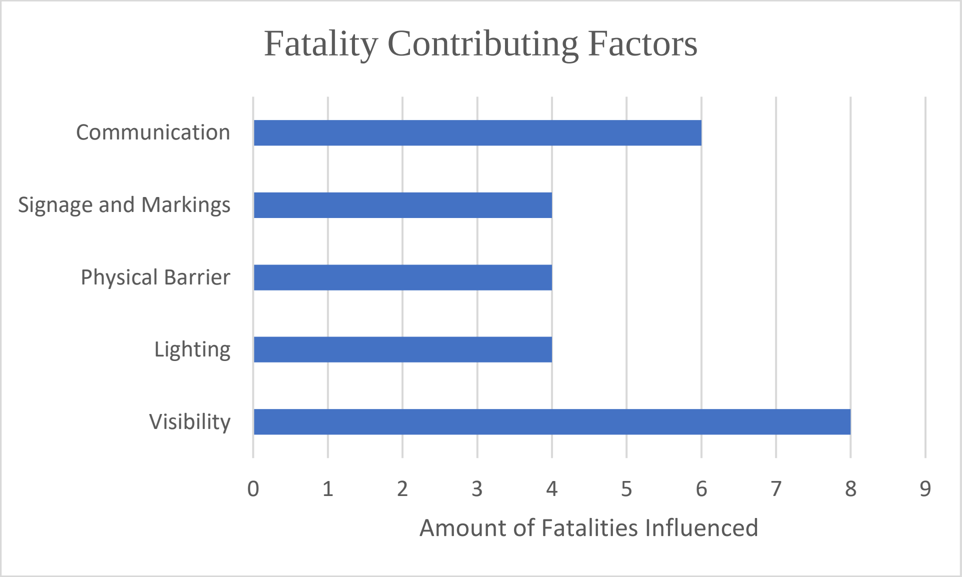

Figure 20. Factors contributing to loader related fatalities.

It is also worth noting that in Section 4.5.1 it was determined that gravitational potential energy remains to most substantial hazardous energy source in the industry and this fact is highlighted by most of the fatality parameters investigated in this report. For the fatalities related to loaders, one of the most frequently occurring causes was loaders falling into open stopes. This has a clear relation to the gravitational potential energy present whenever you have a substantial difference in vertical elevation with no physical obstructions or barriers present. Any large opening, shaft, stope, orepass or bench is a potential candidate for causing a fatality.

The mining industry is continuously progressing towards larger scale operations that also involves mining orebodies at greater depths. This progression results in larger benches, deeper shafts and more potential hazards. It is therefore imperative that the industry continuously evolves its risk management processes to ensure that these hazards are identified and controlled at a rate that exceeds the progression of the introduction of these larger vertical differences that result from the evolution of mining practices. The fact that no less than four loaders fell into open stopes in the last 30 years seems to indicate that the industry is at times too slow to learn from fatalities and to adapt their risk management processes to prevent the recurrence of these fatalities. This relates to Figure 20 that shows that incident investigation reports identified the need for physical barriers to be implemented four times in the last 30 years.

While performing the analysis it was noted that high potential incidents identified multiple occasions where loaders caught on fire due to the hydraulic pipes rupturing and the hydraulic fluid spilling onto hot components. While this has not resulted in any fatalities within the last 30 years, the fact that it keeps recurring is worrying and seems to indicate a persisting issue that might be a ‘ticking time bomb’. The only way to achieve zero fatalities is by evolving our hazard controls at a faster pace than the evolution of the industry and the opportunity for high potential incidents to result in fatalities.

4.5.3 Personal Protective Equipment (PPE) Breaches

The hierarchy of controls dictates that PPE is the lowest or least effective form of risk control. There are unfortunately situations in the mining industry today where the utilisation of PPE can mean the difference between life and death. It is therefore unfortunate that given the importance of PPE, there were still multiple fatalities where the inadequate utilisation of PPE resulted either directly or indirectly in the occurrence of fatal accidents.

Figure 21 illustrates four items of PPE that were highlighted in the investigation reports related to fatalities that occurred over the last 30 years where adequate utilisation of PPE may have prevented the fatalities from occurring. The effects of the hazardous gravitational potential energy is highlighted again with the inadequate use of fall arrest in the form of lanyards and harnesses comprising one of the main influences for the occurrence of fatalities.

Due to the various tasks on a mine site that requires work to be done at substantial heights, it can be very difficult to control the risks related to these tasks with controls that rank higher on the hierarchy of controls than PPE and safe work procedures. It is therefore imperative that employees utilise fall arrest when performing these tasks.

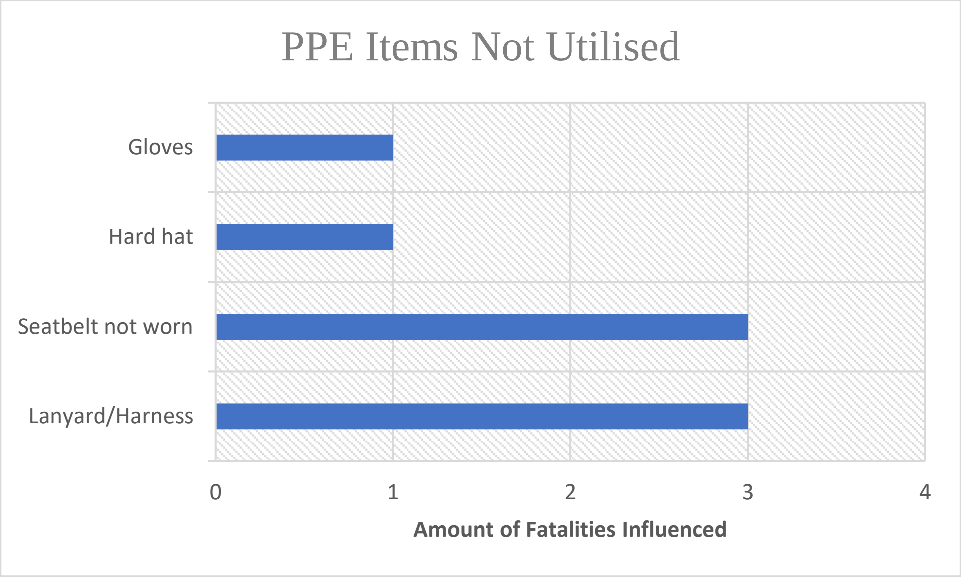

Figure 21. Items of PPE not utilised that contributed directly or indirectly to fatalities.

Figure 22 illustrates some of the fatal causes of accidents that stemmed from the inadequate use of PPE highlighted in Figure 21. By comparing the two figures, it can be deduced that the absence of gloves resulted in electrocution, the absence of a hard hat resulted in being fatally struck by flyrock, the lack of wearing a seatbelt contributing to fatal accidents and the improper or inadequate use of fall arrest resulting in employees falling to their death under the influence of gravity.

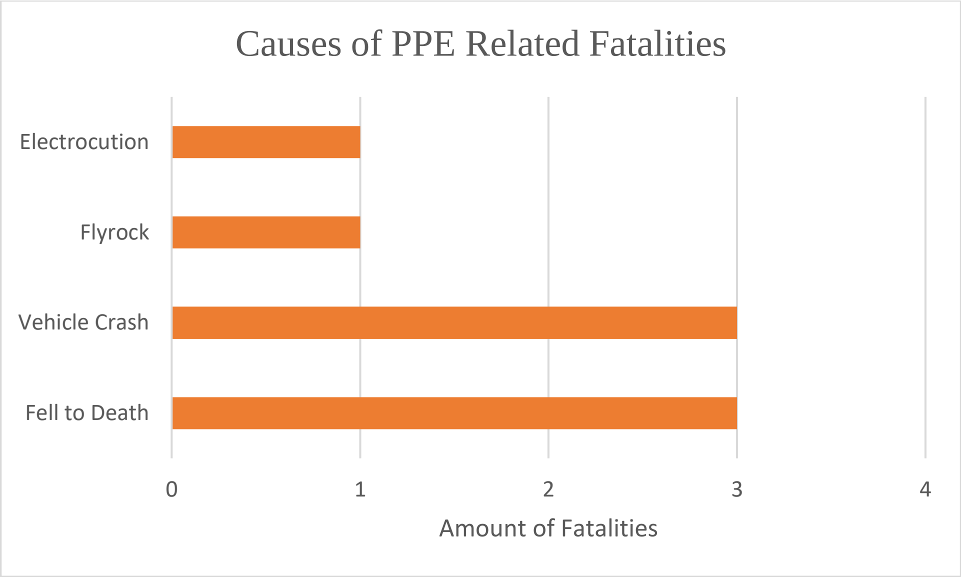

Figure 22. Main causes stemming from inadequate PPE and contributing to fatalities.

4.5.4 Safe Work Procedure (SWP) Inadequacies

Section 4.5.3 discussed how the inadequate employment of PPE, considered to be the least effective control in the hierarchy of controls, can contribute to mining fatalities. While analysing all the fatalities that occurred from 1986 to 2016, it becomes apparent that the administrative group of controls, considered to be slightly more effective than PPE, also exerts a substantial influence on the occurrence of fatalities.

The analysis of the data revealed that 35 of the 62 fatalities or 56.5 % of all fatalities were influenced by inadequate utilisation or quality of the SWPs. Figure 23 illustrates the main issues with SWPs identified from fatality investigation reports. The most significant contributor was SWPs being deliberately ignored by employees. The exact reasons behind why the deceased individuals chose to ignore the SWPs will perhaps never be known. Investigation reports show that even individuals with years of experience in a particular role and an awareness of all the inherent hazards were still found to have breached SWPs with fatal consequences.

Figure 23 indicates that the other issues related to SWPs were the fact that they were either non-existent or inadequate to control the hazards on site. Non-existent SWPs were often related to situations where an employee was performing a task that is very rarely required to be carried out. In other scenarios, a new task was being performed for the first time and therefore no SWP had been developed for it.

In the case of SWPs being inadequate, the situation most often resulted from the fact that the procedures were not regularly audited to ensure they remained up to date and fit for purpose. Mine sites are complex and dynamic environments where the hazards associated with activities performed can evolve very rapidly due to small permutations on site. It is vital that SWPs are regularly audited and updated with employee input to ensure they continue to represent the best practice for safety purposes.

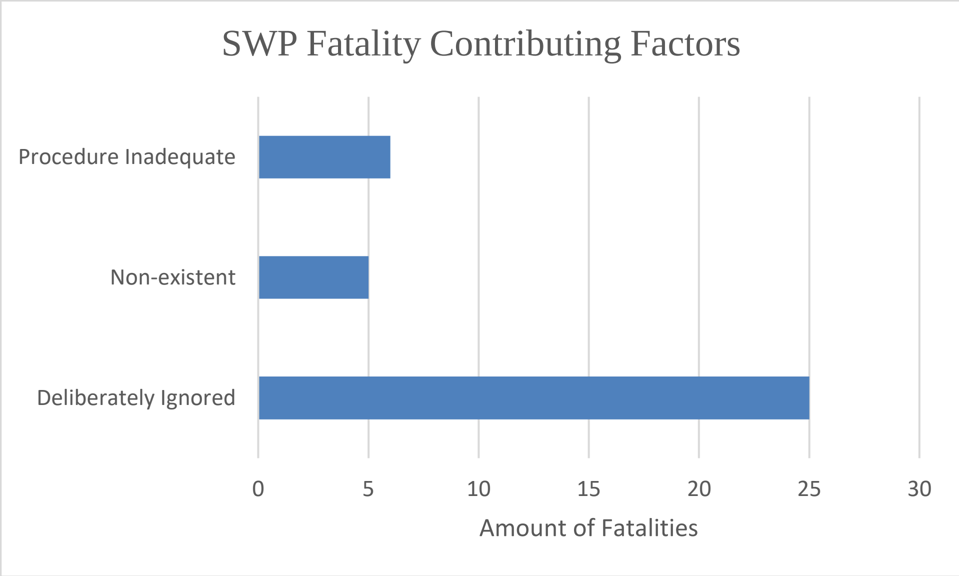

Figure 23. SWP related contributing factors to fatalities.

4.6 OVERLAP BETWEEN CONTRIBUTING FACTORS

Section 4 of this report has discussed multiple contributing factors that have impacted on the fatalities that occurred within Queensland's metalliferous mines and quarrying industry dating back to 1879 but with a specific focus on the 30 years from 1986 to 2016. While all the factors that were discussed individually with some relations between sections drawn, it is important to consider that many of the fatalities were indeed impacted by multiple factors. It is not uncommon for a single fatality to involve a breach of an SWP, inadequate utilisation of PPE and be influenced by gravitational potential energy.

Fatalities are often impacted by a multitude of factors but if major controls can be put in place for all the main issues identified in this report, it would result in multiple layers of controls that would surely improve the industry's ability to inch closer to the ultimate goal of zero fatalities.

5 SUGGESTIONS

The processes of capturing, reporting, distributing and communicating the information related to fatal incidents on site needs to be improved to ensure that every possible measure is taken to prevent the recurrence of fatalities in the industry.

5.1 LOADERS

Physical barriers need to be considered for vertical drops, such as open stopes, where the separation of individuals and the hazards are not possible.

Improvements in awareness and automation needs to occur to remove individuals from dangerous environments. Proximity detection systems, larger and better located signs and markings need to be put in place and adequate lighting should be installed when loaders are required to operate near an open stope.

5.2 PPE AND SWPS

Non-compliance should not be tolerated by companies. A company culture should exist where the correct utilisation of PPE and SWPs are encouraged and praised instead of being tolerated for compliance purposes.

Employees should receive adequate training both during initial inductions and as part of periodic refresher courses to equip them with the necessary skills required to identify hazards and perform adequate risk assessments before tasks are undertaken. This will add an additional layer of control that will prevent the occurrence of fatalities.

SWPs should be audited and updated regularly with input from employees to ensure they remain effective and comprehensive enough to control all the hazards involved in the tasks they relate to.

6 CONCLUSIONS

Safety on mine sites remains one of the key focus areas of the minerals industry. The issue of mining fatalities is often subject to immense political, social and economic pressures to achieve the ambitious goal of a fatality-free industry. The fatalities that receive the most criticism, are those that result from repeated mistakes, causes and control inadequacies; seemingly indicating that the minerals industry had failed to learn from historic fatalities and is too slow to evolve its safety systems.

The common causes, activities and hazards resulting in recurring fatalities in Queensland's metalliferous mines and quarrying industry have been identified and discussed in this paper, realising the stated aims of this project

To contribute to the availability of fatal accident information, this report contains a table of information that highlights key influencing parameters, Appendix A, related to the fatal accidents that occurred in Queensland's metalliferous mines and quarrying industry over the 30-year period from 1986 to 2016. Key areas where the minerals industry can learn from historical fatalities and improve safety performance on site were highlighted by the analysis of the constructed database of information and the following key observations related to fatality data over the last 30 years were made:

1. The most recent legislative acts seem to have had a positive influence on the industry's safety performance. Annual fatality quantities displayed a 77.36 % correlation to annual employment levels within in the industry until the enactment of the Mines Regulation Act 1964 (QLD). After this act, the trend of annual fatality quantities has continuously decreased up to the present day. The enactment of the Mining and Quarrying Safety and Health Act 1999 (QLD), seems to have also reduced the variation of annual fatality quantities to a standard deviation of just 1.06 fatalities over the 15 years after the act was implemented. The effectiveness of the legislation seems to have contributed to annual fatality rates plateauing at a single fatality a year in the most recent years leading up to 2016.

   To breach the current fatality rate plateau and progress the industry closer to the zero-fatality target, a concerted effort is required by the whole industry to effectively eliminate the recurrence of mining fatalities. This will only be achieved by making fatality information readily available and by learning from the historical fatalities to ensure that every effort is made by the industry to prevent fatalities from recurring;

2. Zinc-Lead-Silver and Copper-Gold were found to be the most fatal commodities mined accounting for 68 % of all fatalities. While Zinc-Lead-Silver seems to have been influenced substantially by the amount of fatalities at Mount Isa (21), the Copper-Gold fatalities seem to be resulting from the sheer magnitude of Copper-Gold mines in Queensland;
3. Surface fatalities were discovered to be 10 % more likely than underground fatalities, likely owing to the fact that smelters and processing plants contributed to these figures;
4. It was determined that Tuesdays, Wednesdays and Fridays represented the days of the week when the likelihood of a fatality occurring are the highest, accounting for 54 % of all fatalities. The reasons therefore seemingly relate to both the fatigue and mental state of the employees, with the anticipation of the weekend on Fridays and the realisation of mid-roster days likely affecting the concentration of employees;
5. Mining equipment operators were found to be the occupation most at risk of fatal accidents accounting for 35 % of all the fatalities. Occupations related to manual trades were next accounting for 16 % of all the fatalities;
6. Equipment was found to be involved in 27 or 43.6 % of all the fatalities analysed. The most lethal piece of equipment was determined to be loaders which accounted for 13 or 48 % of all equipment related fatalities. The main causes of loader-related fatalities were individuals being crushed to death, trapped inside an overturned loader, falling into open stopes and collisions with pedestrians. The main factors contributing to these loader-related fatalities were a lack of awareness by the operators and the absence of physical barriers at open stopes;
7. Assessing fatal accidents in terms of the source of uncontrolled energy released, yielded that gravitational potential energy has historically been and remains the most fatal source of energy on site when not adequately controlled. Over the 30-year period from 1986 to 2016, energy releases of a mechanical nature and those related to vehicles were also determined to have substantial impacts on fatality occurrence resulting in a combined 19 fatalities. During the same period, gravity alone accounted for 39 fatalities. The increasing scale and mechanisation of mines were determined to be contributing factors to the results;

8. PPE breaches were also found to have a substantial impact on mining fatalities, with inadequate utilisation resulting in 8 fatalities. The inadequate use of fall arrest and seatbelts were the most significant accounting for 6 of the fatalities;
9. The administrative control measure SWPs were discovered to contribute to 35 or 56.5 % of all fatalities. This was attributable to SWPs being inadequate, non-existent or deliberately ignored by mine site employees; and
10. Gender, age, level of production, depth of operation and mining method had no discernible impacts on fatality rates.

While the effectiveness of the legislative Acts have substantially improved the industry's safety performance, the statistics highlighted by the analyses identifies the aspects of the industry where further improvement can be achieved and it is recommended that the industry focus on eliminating these contributing factors.

The main conclusion reached however is that the only way to learn from historical fatalities and break the cycle of recurring fatalities is by continuously analysing and communicating fatality information to the minerals industry. Industry then needs to utilise this information to rapidly and continuously evolve its Safety and Health Management Systems on mine sites to prevent mistakes and by extent fatalities from being repeated.

7 RECOMMENDATIONS

Future research should be conducted to further update and improve the fatality database to allow more in-depth analysis to take place. This information needs to be available to the public in a centralised location that is simple to find and easy to utilise.

The Department of Natural Resources and Mines could look at improving the availability of fatality data and perhaps create database software that can utilise keywords as inputs to find all the available statistics related to a specific issue. This would enable any member of the public to access a vast array of information related to multiple characteristics associated with mining fatalities. A database such as this would allow for efficient and effective access to information and simplify the process of learning from historical fatalities.

A study similar to this one can be performed for the coal industry and perhaps for other states or countries to compare the results in an attempt to determine where Australia’s industry can learn from other industries that might be outperforming it in certain aspects.

A more detailed investigation could be undertaken to supplement the findings of this report. The fatalities that were identified in this report could be analysed further to determine more intrinsic properties of the fatalities such as latent factors that contributed to the fatalities occurring. A bow-tie analysis can be performed for each fatality to determine what the outcomes beyond the loss of life were, how many controls failed in the lead up to the fatality and what effect the mitigating controls had.

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9 APPENDICES

APPENDIX A – PRELIMINARY FATALITY DATABASE

Date	*Mine*	*Name*	*No.*	*Gender*	*Location*	*Equipment Involved*	*Hazardous Energy Involved*	*Event*	*Contractor*	*Depth of Accident*	*Occupation*	*PPE Breach*	*SWP Inadequate*	*Incident Description*
Saturday, 22 October 2016	Arch Mine Winton - MC 95305	Sidney Cuddy	1	M	Underground	None	Gravity	Inundation/ engulfment	No					
Friday, 13 February 2015	Ernest Henry Mine	Jason Braid	1	M	Underground	None	Gravity	Fall of equipment/ material		1 km	Grader Operator		Y stood on drawpoint rill	On 1 February 2015 a worker sustained hip and vertebrae injuries when he was struck by a rock which rolled down the sub level cave drawpoint rill which he was standing on. He died in hospital while

													recovering from his injuries on 13 February 2015.
Wednesday, 18 June 2014	Isa Mine, Mount Isa	Brett Kelly	1	M	Underground	None	Gravity	Fall of person		1 km	Timberman	Y alone near drawpoint	Fatally injured when he fell into an ore pass.
Wednesday, 6 March 2013	Copper Smelter, Mount Isa	Jordan Taurima	1	M	Surface	Sump Pump	Gravity	Fall of equipment/ material	yes		Labourer		Fatally injured when he was struck by a pump being lifted out of a sump by a mobile crane.
Sunday, 26 August 2012	Mount Moss	Michael Cassidy	1	M	Surface	Loader	Vehicle	Collision with a person			Mining Supervisor		Fatally injured when he was run over by a front-end loader.
Tuesday, 5 June 2012	Moranbah South Quarry	Sean Scovell	1	M	Surface	None	Mechanical	Caught in nip point			Plant Operator		Fatally injured after becoming entangled in a conveyor.

Sunday, 6 March 2011	Opal Miner - Winton	John Kovac	1	M	Underground	None	Gravity	Inundation/ engulfment	Opal Miner		An opal miner, working alone in old shallow underground workings, was fatally injured while removing mullock used to backfill a surface excavation that intersected the underground workings. The material flowed and engulfed him.
Saturday, 4 July 2009	Roseneath Quarry	Waaka Walker	1	M	Surface	None	Vehicle	Rollover	Truck Driver	Y seat belt	Worker truck tipped over and crashed when coming down haul road
Tuesday, 19 May 2009	George Fisher South	Pekka Tuppurainen	1	M	Underground	Loader	Gravity	Fall of vehicle	Loader Operator		Fatally injured when loader he was operating fell into open stope.
Monday, 18	Small Quarries – Rockham	Adam Schultz	1	M	Surface	None	Gravity	Fall of equipment/ material	Maintenance Worker		Fatally injured when struck by falling hopper door of a mobile crusher when he was

August 2008	pton (Castle Creek Quarry)											preparing to remove the door from the crusher.
Thursday, 17 January 2008	Cannington Mine	Michael Auld	1	M	Underground	LV and IT	Vehicle	Collision with another vehicle	yes	375 meter level	Miner	Fatally injured when crushed between a light vehicle and a man basket attached to a loader.
Friday, 15 December 2006	Cannington Mine	Daniel Hensler	1	M	Underground	IT Basket	Gravity	Fall of equipment/ material		350 meters	Trainee Diamond Driller	Fatally injured when the main basket detached from the tool carrier and fell to the ground.
Friday, 27 October 2006	Mineral Exploration Site – Far North Queensland (Watershed	Noel Lovell	1	M	Surface	None	Vehicle	Rollover	yes		Plant Operator	Fatally injured when loader toppled on and crushed him.

	Exploration Project)										
Thursday, 27 July 2006	Small Quarries – Mareeba (Wongabel Quarry)	John A Potter	1	M	Surface	Wheel Loader	Vehicle	Collision with a person	Plant Operator	Y swp not followed	Fatally injured when run over by loader
Monday, 27 June 2005	Bracalba Quarry	Lockyer Bray	1	M	Surface	None	Thermal	Fire	Child		Died in fire in caretaker’s residence
Wednesday, 24 November 2004	Mount Norma	Barry Cusack	1	M	Surface	"Air Trac Drill"	Gravity	Fall of person	Driller		Fatally injured when he fell over face with his trac drill.

Friday, 22 October 2004	Mount Windsor Station	Kerri-Ann McDonald	1	F	Surface	Loader	Vehicle	Collision with a person			Visitor	Fatally injured when she was struck by a front-end loader.
Tuesday, 17 August 2004	Highway Reward Mine	Samuel Pugh	1	M	Underground	None	Gravity	Fall of ground	yes	370 meters	Miner	Fatally injured when he was struck by a rock which fell from open stope into the drawpoint.
Monday, 9 February 2004	Century Lead Zinc Mine	Peter Marshall	1	M	Surface	None	Pressure	Tyre rim failure/rupture			Fitter	Fatally injured when trying to remove a deflated outer rear tyre assembly from the truck when there was a sudden expulsion of air from the inner wheel. This expulsion of air projected the outer assembly 13 metres, striking the deceased.
Friday, 7	Pajingo Gold Mine	Lindsay Pope	1	M	Underground	None	Pressure	Failure of pressure vessel (cylinder - hose - accumulator)			Miner	Fatally injured when he was struck on the head by a compressed air line or fittings from the air line while

March 2003												extending the line underground at the mine.
Friday, 13 December 2002	Highway Reward Mine	Gordon Fogarty	1	M	Surface	Loader	Mechanical	Crushed between a load and a structure	portal	Loader Operator	Y did not follow swp	Fatally injured when he became caught in the articulation point, between the cab and the front mudguard of an Elphinstone 2900 loader.
Tuesday, 2 July 2002	Mount Hay Tourist Mine	Kelvin Hill	1	M	Surface	None	Gravity	Fall of ground		Child		Fatally injured when he was struck by a rock which fell from the face of an excavation where he was fossicking.
Friday, 3 May 2002	Hadleigh Castle Mine	Shane Michael Prowse	1	M	Underground	None	Gravity	Fall of ground		Miner		Fatally injured when struck by a fall of rock at the face of the development heading while charging the face.
Friday, 14 July 2000	Mount Isa Mines - Lead Smelter	Peter James Comerford	1	M	Surface	None	Mechanical	Lifting Yes	2.23 Crusher Level	Rigger		Fatally injured when struck by a heavy load which fell from an overhead carne when being lifted.

	Sinter Plant												
Tuesday, 27 April 1999	Phosphate Hill Mine, WMC Fertilizers	Sang Chul Kim	1	M	Surface	None	Gravity	Fall of person			Y fall arrest	Y not following swp	Fatally injured when he fell from the top of a sulphuric acid tank that was under construction.
Monday, 23 November 1998	Mount Isa - Enterprise Mine	Scott Robert Johnston	1	M	Underground		Gravity	Fall of person		M62 Shaft 30B level	Y fall arrest	Y not addressed by Hazard management plan	Fatally injured when he fell from the deck of a sinking stage in a shaft. Likely he fell inwards through kibble hole with top section of safety rail missing. Did not wear a safety harness.
Sunday, 14 December 1997	Cannington Mine	Phillip Anthony Fowler	1	M	Underground		Electrical	Electric shock	yES	574 metre level		P	Fatally injured when he was touched on the neck by an electrode whilst arc welding in a crib. Did not wear protective gloves. Electrode holder foun to be defective.

Thursday, 19 June 1997	Mount Isa Mines - Scrap metal yard	David Ronald Stratton	1	M	Surface	Loader and tri-axle trailer unit	Mechanical	Crushed between a load and a structure	Yes	0 -Surface		Fatally injured when he became caught between a tracked loader and a semi-trailer whilst his truck was being loaded.
Wednesday, 4 June 1997	Mount Isa Mines - Deep Copper mine	John Charles Barber	1	M	Underground	LHD	Gravity	Fall of vehicle		26 level		Fatally injured when the loader he was operating was reversed into a stope. No physical barriers, shift bosses did not inspect site. Inadequate lighting.
Tuesday, 10 December 1996	Mount Elliot Mine	Rick John Turnbull	1	M	Underground	IT, not responsible	Gravity	Fall of ground		1130 level	Y unsupported ground and lack of hazard/risk assessments	Fatally injured when he was struck by a fall of ground whilst barring down in the Corbould slot drive.

Saturday, 23 November 1996	Selwyn Mine	Brett Grant Duffie	1	M	Surface	Forklift	Gravity	Fall of person	0 - surface	Y gloves	Y	Fatally injured when he fell from the forklift truck he was operating and it crushed him. Unit had no restraining device, inappropriate speed at time of fatality.
Sunday, 27 October 1996	Mount Isa Mines - Deep Copper mine	Barry Arnold Rooks	1	M	Underground	Scissor lift tractor, not responsible	Gravity	Fall of ground	M62 Conveyor Access 20C sublevel	Y no lanyard/harness	P	Fatally injured from a fall of ground whilst installing rock bolts, insufficient ground support for access ground where rock was not competent
Sunday, 6 October 1996	Mount Isa Mines - Lead mine	Wayne Anthony Corry Jackson	1	M	Underground	LHD	Gravity	Fall of vehicle	17d sublevel of 16d8 stope		Y	Fatally injured when the loader he was operating fell into a stope. No spotter (Metal Regulation 1985 part 7.15), inadequate lighting
Tuesday, 4	Mount Isa Mines - Copper	Glen Burrows	1	M	Surface – Copper Concentrator		Gravity	Fall of person	0 - surface		Y exposed ground without	Fatally injured when he fell through the floor in the copper concentrator.

June 1996	Concentrator										temp roof support	
Tuesday, 14 March 1995	Mount Isa Mines	Tony Daniel John Trevor	1	M	Underground	Loco/trucks	Mechanical	Crushed between a load and a structure	5928 crosscut			Fatally injured when he became crushed between two ore wagons in an underground workshop.
Wednesday, 9 November 1994	EPM, Cloncurry	B Carter; R Stalker	2	M	Surface	Aircraft	Gravity	Fall of vehicle	0 - surface		Y	Fatally injured when their aircraft conducting low level geophysical surveys crashed.
Monday, 17 October 1994	Tichum Creek Quarry	Gavin John Milner	1	M	Surface	Dump Truck	Gravity	Fall of vehicle	0 - sufac e			Fatally injured when the dump truck he was operating fell over the quarry face. Hit highwall, was exceeding the speed limit
Monday, 12 Septem	Tick Hill Mine	Kenneth Andrew Slater	1	M	Surface		Explosives	Flyrock	0 - Low grade surface stockpile	Y did not take shelter	Y did not identify hazards, not	Fatally injured when he was struck by flyrock from blasting that was being carried out in a stockpile area.

ber 1994											under excavator	competent or qualified	Multiple safety offences incl. incorrect transport of explosives, incorrect procedures followed, incompetent persons, incorrect controls.
Wednesday, 10 November 1993	West Moreland Mine	Daile Alfred Coffison; Geoffrey Alan Schubert	2	M	Surface	Helicopter	Gravity	Fall of vehicle	Yes	0 - Surface exploration	Y was not wearing seatbelt	Y exceeding speed limit, road not wide enough	Fatally injured when the helicopter they were in for an exploration drilling program crashed. Sling was attached to underside of helicopter, caught on drill rig and shot into roter.
Friday, 2 October 1992	Tick Hill Mine	Sean James Kennedy	1	M	Underground	LHD	Mechanical	Crushed between a load and a structure	Yes	875 sill drive	Y seatbelt	Y exceeding speed limit	Fatally injured when he became crushed between the lip of a loader bucket and an underground development face.
Tuesday, 11	Smacker's Knob Mine	Peter Carl Daniel	1	M	Surface		Gravity	Fall of ground		0 - Surface		Y did not follow swp, did not	Fatally injured when he became buried from a fall of rock from the face where he

June 1991										identify hazards, inadequate training	was working, did not consider incompetent condition of the sandstone face.
Wednesday, 22 May 1991	Mount Isa Mines - Copper Concentrator	Michael John Gorey	1	M	Surface		Gravity	Fall of Yes person	0 - Surface, Mullock Bin	Y not observed or followed	Fatally injured when he fell through an opening at the top of a bin.
Tuesday, 14 May 1991	Cracow Mine	Anthony Mihalj	1	M	Underground	sig machine/air leg	Gravity	Fall of ground	NS 12 - e2 stope	Y sling attached to the chopper	Fatally injured whilst he was drilling blast holes and rock fell onto him, should have been using flatbacking to advance the stope North
Sunday, 21 April 1991	Mount Isa Mines - Lead Smelter	John Phillip Baira	1	M	Surface	Crane	Gravity	Fall of equipment/ material	0 - Surface	Y no swp for working in bucket	Fatally injured from burns he sustained form molten lead which spilt from the ladle when the hook became detached, locking bolt and nut failed or unscrewed.

Wednesday, 13 March 1991	Cracow Mine	Jusuf Vrbic	1	M	Underground		Gravity	Inundation/ engulfment		No 6 draw point NS 12 ore body		Fatally injured when a hang-up in a draw-point collapsed on him.
Thursday, 7 February 1991	Mount Isa Mines - Lead Smelter	David Anthony Kelly	1	M	Surface	Water jet tank cleaning equipment	Gravity	Fall of a structure	Yes	0 - Surface, Gas cooling tower		Fatally injured when he was crushed by falling steelwork when a tower collapsed.
Saturday, 26 January 1991	Mount Isa Mines	Gary Michael Martin	1	M	Underground	LHD	Gravity	Fall of vehicle		R405 stope below 18b sublevel	Y did not follow swp	Fatally injured when he drove his unit through a warning barricade and fell into an open stope, unfamiliar with stope locations
Friday, 5 October 1990	Greenvale Mine	Malcolm Peter Wolfenden	1	M	Surface	Dump truck	Vehicle	Collision with another vehicle		0 - Surface		Fatally injured when the empty off-road dump truck he was driving skidded across the haul road and collided with

											another truck causing him to be thrown from the cab.
Thursday, 4 October 1990	Hilton Mine	Martin Henry Rowlands	1	M	Underground	Jumbo	Gravity	Fall of ground	KD51 incline 9a sublevel		Fatally injured when a slab of rock fell from the side wall pinning him against the boom of a drill jumbo. The rock bolt holes had been drilled, but the bolts had not yet been inserted.
Wednesday, 25 July 1990	Isa Mine, Mount Isa	L J White	1	M	Underground		Gravity	Fall of person		Y floor not fixed according to Aus Standard 1657, no swp to perform task or measure completion	Fatally injured whilst standing on a ladder which was hurled to the ground.

Monday, 4 June 1990	Isa Mine, Mount Isa	Thomas Douglas Lawrence Anderson	1	M	Surface	Loco/wagon	Gravity	Fall of person	0 - Surface, Gardenia Gate crossing		Fatally injured when he fell and was run over by the first wagon of a cement train.
Wednesday, 15 November 1989	Horn Island Mine	W Nelliman	1	M	Surface	LV/Haul Truck	Vehicle	Collision with another vehicle	0 - Surface	Y did not follow swp	Fatally injured when he was crushed in the cab of his 4WD when a CAT haul truck ran over his vehicle.
Tuesday, 26 September 1989	Isa Mine, Mount Isa	J Beavan	1	M	Underground	Loco	Mechanical	Crushed between a load and a structure		Y did not follow swp	Fatally injured when he was crushed between flying rail of a loco and the wall of a cross-cut while a rake of trucks was being loaded from a chute.
Sunday, 30	Cracow Mine	S Levy	1	M	Surface	LHD	Vehicle	Rollover		Y did not follow swp	Fatally injured when the loader he was operating left the road and overturned.

April 1989											
Monday, 13 March 1989	Mount Isa Mines	Gregory George Nicholson	1	M	Underground		Gravity	Inundation/ engulfment	N73 by-pass 19 level		Fatally injured when he became overwhelmed by a rush of fill whilst operating a load-haul dump.
Thursday, 5 January 1989	Carpentaria Gold Mine	D J Oats	1	M	Surface		Gravity	Inundation/ engulfment		Y did not follow sw[	Fatally injured when he became trapped in a mill hole at the base of a ore stockpile.
Friday, 20 May 1988	Isa Mine, Mount Isa	G Neville	1	M	Underground	LHD	Vehicle	Collison with a person			Fatally injured when he was run over by a Wagner ST5E LHD unit he had been operating.
Tuesday, 9 February 1988	Isa Mine, Mount Isa	W J Barry	1	M	Surface		Electrical	Electric shock		Y did not follow swp	Fatally injured when he was electrocuted when he placed his fingers in close proximity to live 6.6 kV wires.

Tuesday, 9 February 1988	Kidston Mine	P Mayne	1	M	Underground	LHD	Vehicle	Collision with a person		Y did not follow swp	Fatally injured when he was run down by a Wagner ST5E unit.
Monday, 17 February 1986	Isa Mine, Mount Isa	J Pippenbacher	1	M	Underground		Gravity	Inundation/ engulfment			Fatally injured when he was buried by a sudden rush of saturated fill whilst mucking de-slimed mill tailings.

APPENDIX B – PROJECT GANTT CHART

Name	Begin date	End date
Project Progress Report	28/05/17	28/05/17
Project Plan Agreement	1/06/17	1/06/17
Consult mining industry safety specialists	24/07/17	4/08/17
Continuous Formatting and Editing	1/06/17	26/10/17
Ongoing Supervisor Consultation	1/06/17	26/10/17
Research incident influencing factors to complete fatality database	5/06/17	6/08/17
Complete comparative analysis of Queensland's Coal and Metalliferous Safety Legislation	1/06/17	2/08/17
Fatality database is completed, including all influencing factors	7/08/17	7/08/17
Statistical analysis of fatality database	7/08/17	24/08/17
All fatalities comprehensively analysed	25/08/17	25/08/17
Discussion of results in terms of current regulatory frameworks	25/08/17	1/09/17
Conclusion on the effectiveness of analysis and importance of findings	2/09/17	7/09/17
Recommendations for improving mining safety and future research requirements	11/09/17	22/09/17
Final formatting, editing and proof-reading	23/09/17	6/10/17
Creation of presentation slides	9/09/17	25/09/17
Thesis Presentation Slides	26/09/17	26/09/17
Thesis Synopsis	8/09/17	8/09/17
Project Presentation	29/09/17	29/09/17
Watch AusIMM webinar on mine safety	28/09/17	28/09/17
Incorporate webinar learnings into thesis	29/09/17	2/10/17
Examiner's Thesis Copy	9/10/17	9/10/17
AusIMM Proceedings	27/10/17	27/10/17
Implement Supervisor's Recommendations	12/10/17	4/11/17
Revised Thesis Copy	6/11/17	6/11/17

Figure 24. Activities required to successfully complete project.

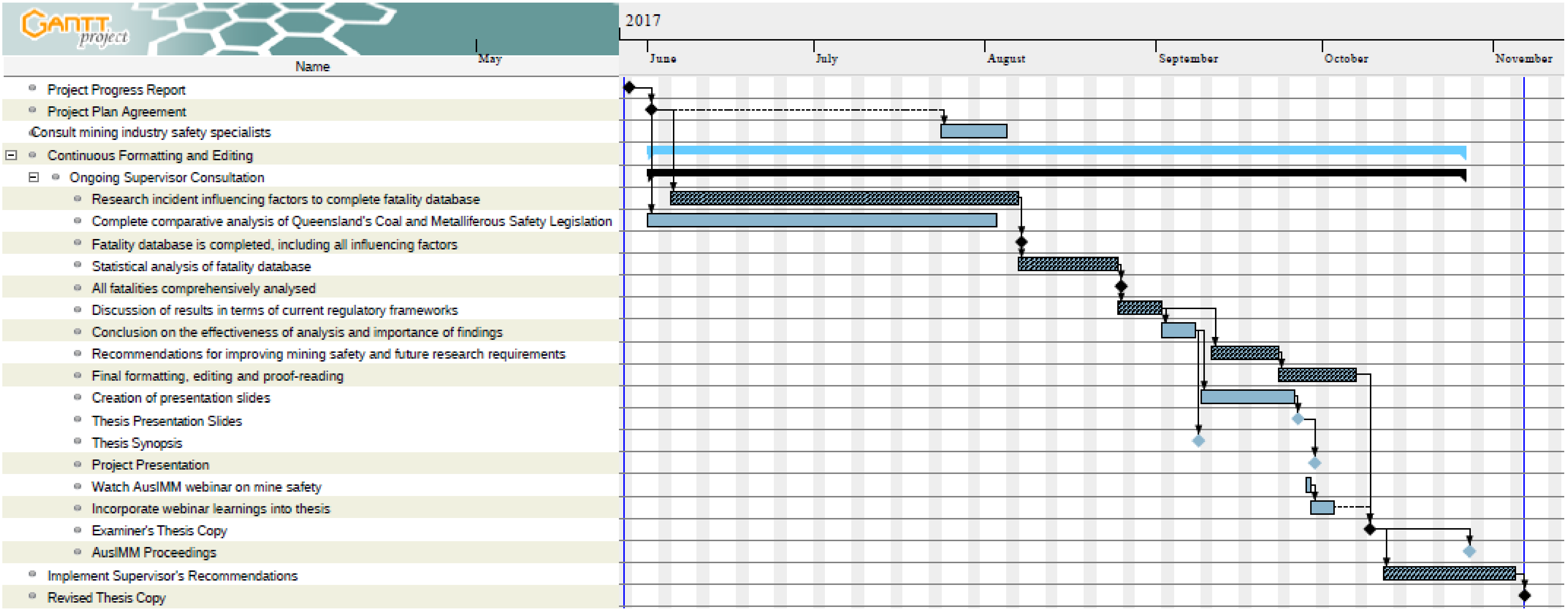

Figure 25. Gantt chart highlighting required activities and critical path applicable to the project.

APPENDIX C – GENERAL FATALITY CAUSES

Table 8
Fatality causes identified by authors and legislation.

Cause Identified	*Amount of sources identifying the cause*	*Sources of identification*
Electrocution	6	(Department of Mines and Petroleum; MHSR 2007; Noon and MacNeill, 2014; MQSHR 2001; MSHA, 2017; Quinlan, 2014)
Rock/ground fall	6	(Department of Mines and Petroleum; MHSR 2007; Noon and MacNeill, 2014; MQSHR 2001; MSHA, 2017; Quinlan, 2014)
Inrush	5	(Department of Mines and Petroleum; MHSR 2007; Noon and MacNeill, 2014; MQSHR 2001; Quinlan, 2014)
Fire	5	(MHSR 2007; Noon and MacNeill, 2014;

		MQSHR 2001; MSHA, 2017; Quinlan, 2014)
Pit wall failure	4	(Department of Mines and Petroleum; Noon and MacNeill, 2014; MSHA, 2017; Quinlan, 2014)
Explosion (Rock breakage agents)	4	(MHSR 2007; Noon and MacNeill, 2014; MSHA, 2017; Quinlan, 2014)
Gas explosion	4	(Noon and MacNeill, 2014; MQSHR 2001; MSHA, 2017; Quinlan, 2014)
Loss of control of vehicle (including run-aways, machinery)	3	(Department of Mines and Petroleum; MHSR 2007; MQSHR 2001)
Escape of fluid under high pressure	3	(MHSR 2007; Noon and MacNeill, 2014; MSHA, 2017)
Fall from heights	3	(Noon and MacNeill, 2014;

		MSHA, 2017; Quinlan, 2014)
Vehicle collisions	2	(Department of Mines and Petroleum; MHSR 2007)
Tyre Handling	2	(Department of Mines and Petroleum; Noon and MacNeill, 2014)
Asphyxiation	2	(MHSR 2007; Noon and MacNeill, 2014)
Uncontrolled issue of gas or fluid	2	(MHSR 2007; Quinlan, 2014)
Failure of winding, haulage or lifting equipment	2	(MHSR 2007; MQSHR 2001)
Immersion in liquid	2	(MQSHR 2001; Noon and MacNeill, 2014)
Inundation	2	(MSHA, 2017; Quinlan, 2014)
Equipment/Machinery	2	(MSHA, 2017; Quinlan, 2014).
Fall arrest failure	1	(Department of Mines and Petroleum)

Departure from OEM procedures	1	(Department of Mines and Petroleum)
Vehicle over edge	1	(Department of Mines and Petroleum)
Overturning of vehicle (including machinery)	1	(MHSR 2007)
Fly rock	1	(MHSR 2007)
Airblast	1	(MHSR 2007)
Burial of machinery	1	(MHSR 2007)
Structural failure of plant	1	(MQSHR 2001)
Exposure to hazardous substance	1	(MQSHR 2001)
Contact with moving or rotating plant	1	(Noon and MacNeill, 2014)
Windblast	1	(Noon and MacNeill, 2014)
Fall of material	1	(MSHA, 2017)
Material Handling	1	(MSHA, 2017)
Hand Tools	1	(MSHA, 2017)
Non-powered haulage	1	(MSHA, 2017)
Entrapment	1	(Quinlan, 2014)